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THE GIBBON HEART-LUNG MACHINE: ORIGIN, NATIONAL AND LOCAL STATUS*

DAVID T. DODD, M.D.

Memphis, Tennessee

For the past quarter of a century men have been searching diligently for a suitable mechanical heart-lung substitute. There is a dual purpose in the development of such a machine. First, such an apparatus should prove useful in temporarily taking over a part of the circulation in patients in whom the function of either the heart or the lungs, or both, is impaired to such an extent that life is endangered. Secondly, the perfection of such an apparatus would make possible operations within the chambers of the heart without fatal loss of blood and under direct vision.

Although organ perfusion by artificial means has been common to laboratories of the experimental physiologist and pharmacologist for years, the first clinical surgeon to adopt a keen interest in this problem was John H. Gibbon Jr. It was under his supervision that the first total body perfusion in the experimental animal with survival was accomplished. Most of the machines currently in use in this country are in some fashion based upon the principles which he developed from his pioneer work. And because the machine which his efforts have made available commercially is presently in experimental operation at the Surgical Research Laboratories of the University of Tennessee, it is fitting that a history of extracorporeal circulation as he helped to mold it originate from here.

The basic elements of an extracorporeal blood circuit that will perform the cardiorespiratory functions are two pumps to perform the work of the right and left sides of the heart and a device which will saturate the blood with oxygen and permit the escape of carbon dioxide. Although the clarity and simplicity of the fundamental requirements were apparent from the outset, the course of development was beset by many obstacles. The story of the current pumps and oxygenators is one of adoption, modification, rejection and readoption of numerous and various precursors.

Basically, two kinds of pumps have been used by Gibbon. One, devised by Dale and Schuster[4] of England in 1928 and modified by I. deBurgh Daly[5] in 1932, is represented diagrammatically in figure 1. The inlet and exhaust port holes of a seven horsepower Austin engine were closed and the four cylinders used as air compressors by driving them with an electric motor. Each cylinder was in contact with a glass cylinder containing a heavy latex finger stall (*a* and *b* of fig. 1). The finger stall was equipped with a Y-tube, one limb (*e*) forming an inlet equipped with an intake valve separating the finger stall from a venous reservoir (*d*) above. The second limb of the Y-tube (*f*), equipped with an outflow valve, acted as an arterial outflow. With each cycle of the engine piston air was alternately compressed and decompressed around the finger stall causing filling and emptying of the latter. The degree of compression, and consequently the output, was controlled by adjusting the opening of the side tube (*c*). The entire glass apparatus was surrounded by a glasswalled thermostat (*g*) filled with water kept at 37 to 39° C.

Although capable of high rates of flow this pump was objectionable in that it was large and cumbersome and contained internal valves.

* From the University of Tennessee, Memphis, Tennessee.

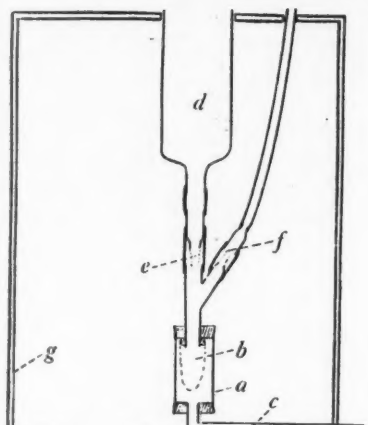

FIG. 1. Diagram of the de Burg Daly modified Dale-Schuster pump used in the original Gibbon heart-lung machine. (Courtesy of Cambridge University Press.)

The latter were objectionable in that they produced some trauma to cells and stagnant areas which promoted the formation of fibrin. The device was later discarded in favor of the DeBakey[3] constant ejection roller type. As reproduced in figure 2, this type of pump consists of a shaft with a pair of rollers mounted on each end. During each revolution of the shaft, each roller compresses a tube mounted against a 180° fixed side of the pump base. As the shaft rotates in one direction the rollers turn in the opposite, thus eliminating friction and grinding of the sides of the compressed tube. The pump is so constructed that one roller is always in contact with and compressing the tubing. By adjusting the rollers to be almost completely occlusive so as not to traumatize blood cells, a milking action occurs in front of them with negative pressure behind creating a suction effect. Thus internal valves along with other sources of friction and trauma were eliminated.

As originally designed by DeBakey for use in direct cross transfusion the pump was manually operated. Gibbon[8] added electric motors with a twenty-to-one gear ratio and rheostatically controlled armature current making it possible to control the speed of the motors and, therefore, the output of the pumps.

The most important part of any total perfusion apparatus is the mechanism for oxygenating venous blood. The perfection of such an apparatus has been the problem in making extracorporeal circulation practical. In order to introduce an adequate amount of oxygen into a swiftly moving stream of blood, the blood must be spread out into a very thin film. By 1937, such a film had been produced in a variety of ways resulting in many types of oxygenators.

Hooker,[12] in 1915, devised a revolving flat disc, which threw a stream of blood, led to its center from above, into a thin film against the sides of an inverted glass bell jar. Hooker gave no figures as to the rate of blood flow, volume of blood contained, or amount of oxygen introduced per minute by this apparatus. The obvious drawbacks were the production of foam and lack of assurance that the blood would remain in a film on the sides of the glass bell jar.

Also in 1915, Richards and Drinker[15] described a method of oxygenating blood by allowing it to run through a silk curtain exposed to oxygen. As the blood saturated the curtain there were two surfaces exposed to oxygen. The rate of flow was 50 cc. per minute and 3.75 cc. of oxygen per minute were thereby introduced. In 1922,

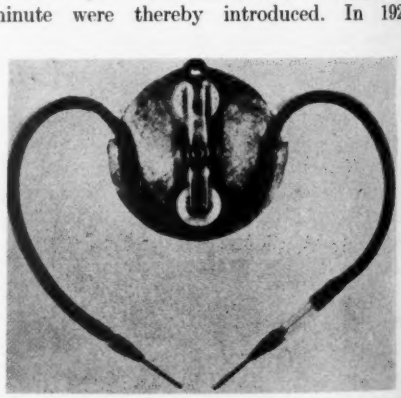

FIG. 2. Photographic reproduction of the original DeBakey roller pump. Later modified by Gibbon. (Courtesy of Louisiana Printing Co.)

Drinker, Drinker and Lund[6] used a Hooker type of oxygenator which accommodated a blood flow of from 10 to 60 cc. per minute. Barnstein,[1] in 1926, oxygenated blood to perfuse the hind limbs of dogs by passing the fluid through a jar filled with glass beads. Oxygen was blown through this chamber in the direction of blood flow. Blood flowed through the apparatus at the rate of 500 cc. per minute.

In 1928, Bayliss, Fee and Ogden[9] devised an oxygenator consisting of a tier of rotating discs. The blood thrown to the side of the apparatus from the top disc was again led into the center by a stationary funnel shaped retaining wall which dropped the blood upon the second revolving disc. Oxygen was then blown into the apparatus which greatly increased its efficiency. The surface area of the filming device was approximately 1500 sq. in. It held 54 cc. of blood, accomodated rates of flow up to 260 cc. per minute and was capable of introducing as much as 27 cc. of oxygen per minute into the blood.

In general, the difficulties encountered with these oxygenators were foaming, frothing, hemolysis from trauma to the red cells and production of vasoconstrictor substances in the blood from mechanical agitation. Probably the major disadvantage was that they contained a large quantity of blood passing at a slow rate. What was needed was a large surface area for filming which contained a relatively small quantity of blood flowing at a rapid rate.

In 1937, Gibbon[7] reported the results of an experiment he devised for artificial maintenance of circulation during experimental occlusion of the pulmonary artery. Working in defiance of the then popular Trendelenberg operation for massive pulmonary embolism, he introduced an oxygenator of large surface-volume ratio.[9] As shown diagrammatically in figure 3, this device consisted of a cylinder (*a*) mounted upon roller bearings and revolved by an electric motor. A jet of blood was fed to the top of the cylinder which filmed down its inner surface as the cylinder rotated. The space for blood-oxygen contact was narrowed by placing in the center of the revolving drum a stationary, hollow cylinder which did not quite make contact (*c*). A stream of oxygen was then fed into the filming chamber from below (*d*). The oxygenated blood was collected in a small glass reservoir at the bottom (*b*). Capable of introducing oxygen up to 18 cc.

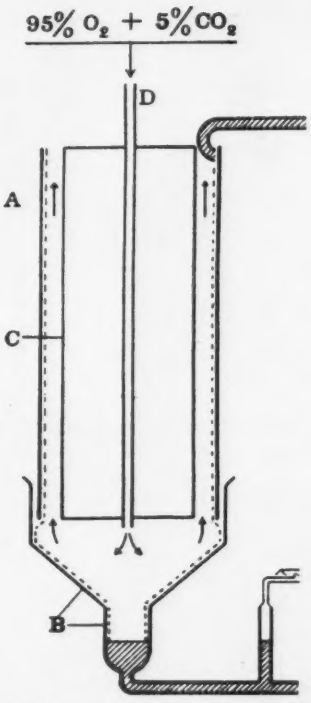

FIG. 3. Diagram of the original revolving cylinder oxygenator designed by Gibbon. (Courtesy of American Medical Association, Publishers.)

per minute, this oxygenator accommodated rates of flow from 50 to 600 cc. per minute without foaming. The filming area consisted of 2300 sq. cm.

By combining his oxygenator with the de Burgh Daly modified Dale-Schuster pumps and adding electronic and temperature controls as well as bubble traps, Gibbon constructed a heart-lung machine. It is shown in figure 4, photographically reproduced with permission of the publisher. In 1937, Gibbon reported, for the first time to the best of anyone's knowledge, the successful total heart-lung bypass in the experimental animal with survival. In three instances animals were able to resume their cardiopulmonary functions after total occlusion of the pulmonary artery and total body perfusions for periods of 30, 33 and 39 minutes respectively. Although none of the animals survived for more than four hours after the perfusion, it may safely be said that this was the beginning of an era of intracardiac surgery.

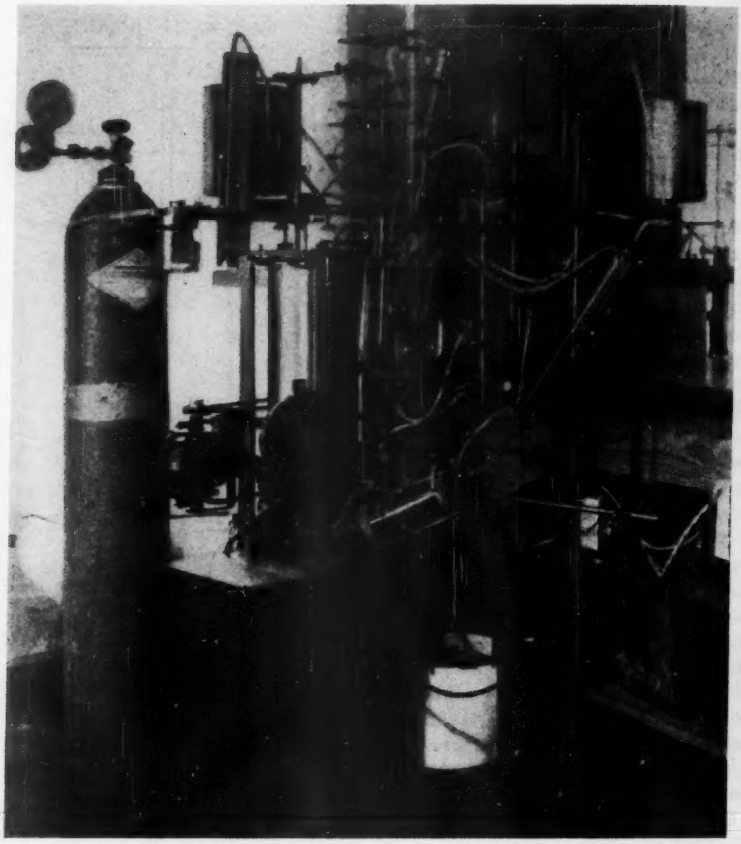

FIG. 4. The original Gibbon heart-lung machine. With this apparatus Gibbon reported the first total body perfusion with heart-lung by-pass in 1937. (Courtesy of American Medical Association, Publishers.)

This particular model did not introduce enough oxygen into venous blood to maintain life in a large animal. Instead of building a larger oxygenator, however, Gibbon continued his studies with smaller animals. A similar device, modified, however, by the substitution of the DeBakey pumps for the Dale-Schuster pumping principle, was used for perfusion experiments in cats. In 1939,[8] Gibbon reported successful perfusion of 13 cats with total occlusion of the pulmonary artery for from 10 to 25 minutes. Five animals lived for periods from 24 to 48 hours, four, from 8 to 23 days and four, from 1 to 9 months. The latter long term survivors were normal in every respect. This achievement constituted the first report of prolonged survival after temporary substitution of a mechanical apparatus for the heart and lungs in the experimental animal.

Apparently, if the oxygenator capabilities could be made proportional to the oxygen demands of the animal, extracorporeal circulation would be a practical reality. One could foresee clinical applications of the machine. The next logical step was the development of an oxygenator of a capacity adaptable to human use. In August, 1941, Gibbon and Kraul[10] devised a larger device (fig. 5) which was capable of introducing 60 per cent more oxygen. Based upon the revolving cylinder principle but of improved design, it introduced 30 cc. of oxygen per minute at rates of flow ranging from 100 to 500 cc. per minute. Foaming was eliminated and only slight hemolysis occurred up to periods of 45 minutes. The area available for filming was 4000 sq. cm., a 58 per cent increase over the oxygenator previously described.

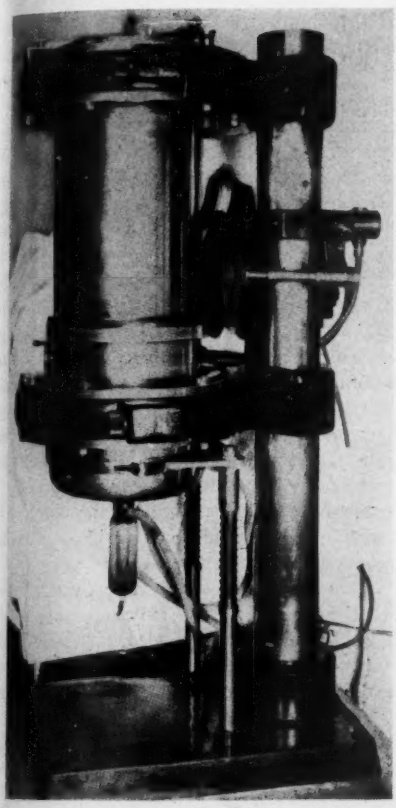

FIG. 5. Photographic reproduction of the second revolving cylinder oxygenator designed and reported upon by Gibbon in 1941. (Courtesy of the C. V. Mosby Co.)

Advances in thoracic surgery and endotracheal anesthesia made possible bolder application of the heart-lung apparatus. In 1951, Stokes and Gibbon[17] opened the chest and cannulated the superior and inferior vena cava directly through the right auricular appendage for recovery of venous blood. By returning oxygenated blood in a central direction through a carotid artery, the heart and lungs were bypassed with occlusion of the vena cava. Eight dogs survived caval occlusion for periods ranging from 30 to 46 minutes. Four of the animals remained normal 8 to 10 months later. Still hemolysis and deficient oxygenation contributed to the failure of several animals to survive. More consistent success in the laboratory was necessary before clinical application could be considered.

The next major advancement came from the Department of Surgical Research of the Jefferson Medical College of Philadelphia, with which Gibbon was then associated. Stokes and Flick[16] demonstrated that the creation of turbulence in the blood film increased its efficiency for gas exchange approximately eight times. This finding gave birth to the screening devices currently in use for filming and oxygenation of blood in the artificial lung.

Various turbulence producing surfaces were investigated. Of those studied, stainless steel screens were found to be the most efficient. *This was true if* the screens were made of stainless steel wire 0.029 inches in diameter with rectangular meshes placed in the horizontal plane.[14]

The first screen oxygenator was constructed in the form of a vertical cylinder. As shown in

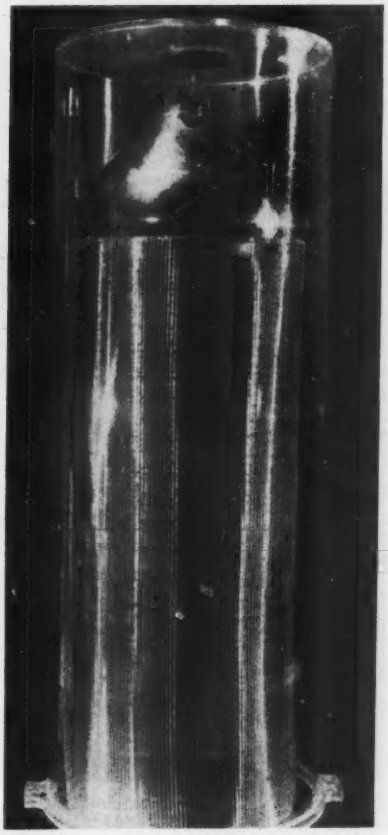

FIG. 6. The first screen oxygenator reported upon by Miller and Gibbon in 1951. (Courtesy of J. B. Lippincott Co.)

figure 6 this cylinder was capped by a bullet shaped head of stainless steel. Blood was distributed over this by a revolving jet and was then passed over the screen in the form of a turbulent film. This apparatus was capable of 95 per cent saturation of blood at flow rates up to 1000 cc. per minute.

In order to carry the entire circulation of average sized dogs it is necessary to have an oxygenator capable of increasing the saturation of blood with oxygen from 65 to 95 per cent at flow rates in the neighborhood of 2000 cc. per minute. A vertical cylinder of the proportion thus required would be cumbersome, for it would require a screen area of 8000 sq. cm. The geometric form was therefore changed to a series of flat screens arranged in parallel and suspended in a clear plastic case.

Through the cooperation of International Business Machine Corporation, Gibbon and his associates constructed the battery type of oxygenator, photographically reproduced in figure 7. This contained a filming area of 8,235 sq. cm. and allowed flow rates up to 2000 cc. per minute—the greatest capacity yet achieved.

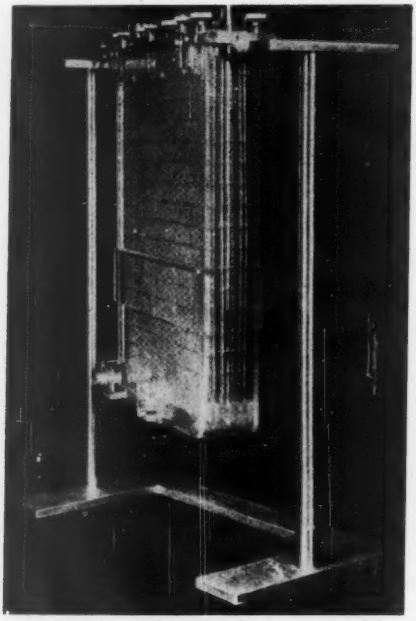

FIG. 7. Photograph of the original battery type screen filming device built for Gibbon by International Business Machine. (Courtesy of J. B. Lippincott Co.)

Using this design the next major step was the accomplishment of intracardiac surgery in the experimental animal. In 1953, Miller, Gibbon and others[13] reported the successful closure of a previously produced interatrial septal defect under direct vision with the assistance of the screen oxygenator. Later, in 1954, Gibbon and associates[11] also reported upon the production and closure of interventricular septal defects under direct vision with survival in 12 of 20 animals. All deaths were attributable to operative complications and not to the mechanical device.

In March, 1954, Gibbon[11] reported upon his first clinical trials of open heart surgery with the use of his heart-lung machine. Four human cases were tried with survival in one case. The survivor, an 18-year-old girl, had an interatrial septal defect which was repaired, and when last reported the patient was living and well. No deaths in this series were attributable to the machine but were due to errors in diagnosis and technique.

In the past few years a wave of eagerness has swept the medical profession on an international scale. There is hardly a medical center in this country that does not have a heart-lung machine of some type. Those that do not are seeking ways to acquire one.

A model based upon the Gibbon principle built by the Mark Company of Randolph, Massachusetts, is now available commercially. One such device, shown pictorially in figure 8, is now in experimental operation at the Surgery Research Laboratories of the University of Tennessee. The acquisition of this machine was made possible through grants from the American and Memphis Heart Association. Successful clinical application is dependent upon the development of close team work among surgeons, cardiologists, pathologists and technicans. Many inherent problems of the machine must be overcome and the device must be adapted to the situation of the locale in which it is being operated. Further study in the experimental laboratory is necessary. Techniques are being developed and an animal survival series is being run. To date the survival rate is approximately 80 per cent with total heart-lung bypass for periods of 30 minutes with cardiotomy. Clinical application in the very near future can be anticipated.

To open the heart and surgically attack lesions therein represents one of the frontiers of modern

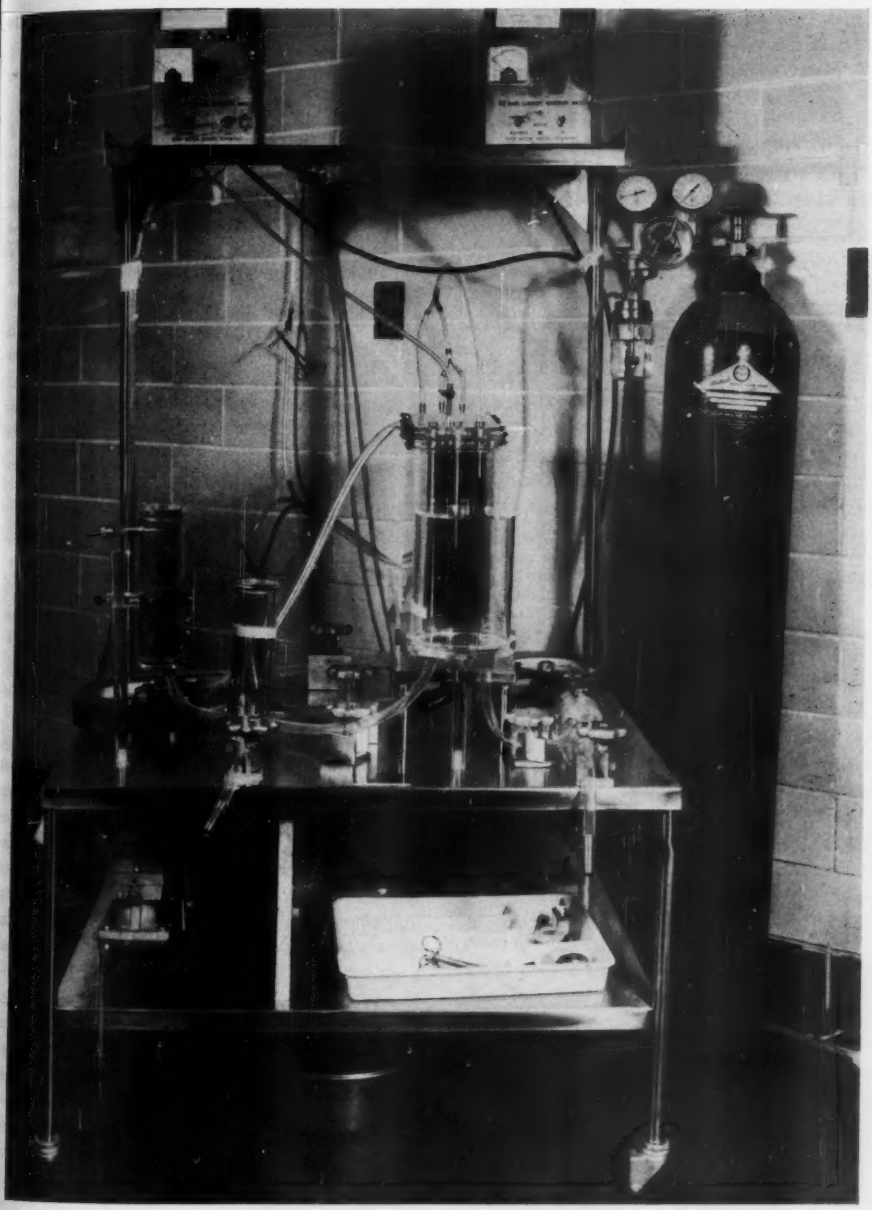

FIG. 8. Commercial model of Gibbon heart-lung machine currently in experimental operation at the University of Tennessee Surgery Research Laboratory. This machine was made available through grants from the American and Memphis Heart Associations.

surgery. One can stop only to wonder whether the heart machine of 1957 is the automobile of 1905. Many advances remain to be made.

SUMMARY

An attempt has been made to give in an orderly fashion the major sequence of events which have taken place in the development of the Gibbon heart-lung machine.

899 Madison Ave.
Memphis, Tenn.

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ADRENOCORTICAL RESERVE IN CHRONICALLY ILL SURGICAL PATIENTS*

C. E. JABBOUR, M.D.

Memphis, Tennessee

There currently exists a considerable interest in the possible usefulness of ACTH and cortisone in debilitated patients who require surgery. Hume and Moore[1] and Cole and his associates[2] have reported favorable results concerning the empiric use of these agents in individuals who did not exhibit clinical evidence of adrenocortical insufficiency. The purpose of the present study has been to attempt to identify debilitated patients with a limited adrenocortical reserve and to define the incidence of such cases.

METHODS AND PROCEDURE

The subjects for this study were chosen because of marked weight loss due to advanced malignancy or, in one instance, because of severe debility due to a ruptured appendix with widespread peritonitis in an elderly woman (table 1). The intravenous ACTH test of Renold and his associates[3] was employed to measure adrenocortical reserve. During a 24-hour control period the total eosinophil count (eosin-acetone technique) was determined and the urine collected for 17-ketosteroids[4] and corticoid[5] analyses. On the following day the patient received intravenously over an 8-hour period 1000 cc. of glucose or saline solution containing 20 units of ACTH (Armour, lot no. M62809 c). Total eosinophil counts were made before and after the infusion and again a complete 24-hour urine collection was made. In general the procedure used during the second period was again employed during a third 24-hour period. Finally, in a number of subjects a fourth day was employed as a second control period. The response of several of these individuals to operation was also studied.

Normal values for 17-ketosteroid excretion in our laboratory range from 5 to 15 mg. in women and from 7 to 21 mg. in men. Normal values for corticoid excretion range from 5 to 8 mg. in both sexes. It is, of course, not easy to set definite "normal" limits for the total eosinophil counts. However, rarely is the initial count below 50 cells per cubic millimeter in the absence of some type of stress stimulus and control counts which exceed 400 cells per cubic millimeter are definitely unusual in the presence of actively functioning adrenal cortices.

As stated previously, the urinary excretion of corticoids was measured in addition to 17-ketosteroid excretion. However, the control values in two of the "normal" subjects, as measured in the urine excreted shortly after admission to the hospital for a major operation, were elevated; therefore, these values are omitted from the present study.

To confirm and buttress the data reported by Renold and his associates in 41 normal subjects, five additional normal subjects have been studied by us to date. As shown in figure 1, the intravenous infusion of 20 units of ACTH over an 8-hour period in our five apparently normal subjects produced the characteristic response in the 17-ketosteroid excretion in all except one individual. This patient, S. E., was the oldest of this group and this may have contributed to the absence of a rise in 17-ketosteroid excretion. However, the corticoid excretion (which is not shown here) also failed to rise. The low total eosinophil count in this subject as well as his tolerance for operation was evidence that there was at least some degree of adrenocortical activity. The excretion of 17-ketosteroids as exhibited by patient H. E. is not commonly elevated following operation. Thus operation, which usually causes an increase in corticoid excretion only, is somewhat different from ACTH stimulation which usually causes an increase in 17-ketosteroid and corticoid excretion.

Figure 2 illustrates the response of five patients who had advanced gastric malignancy. Three patients exhibited a relatively normal response, but the other two subjects are of particular interest. Note the absence of a significant fall in the total eosinophil count following ACTH in patient G. J. on the first day of infusion and the mild rise in 17-ketosteroid excretion on both days. Also note that when 40 units of ACTH instead of 20 units were administered on the fourteenth postoperative day, the excretion of

* From the University of Tennessee, Memphis, Tennessee.

TABLE 1

Patients	Age	Sex	Diagnosis	Weight Loss
				lb.
1. W. B.	60	M	Inguinal hernia	None
2. H. E.	48	M	Inguinal hernia	None
3. P. B.	40	M	Inguinal hernia	None
4. A. O.	28	M	Inguinal hernia	None
5. S. E.	68	M	Inguinal hernia	None
6. D. J.	61	M	Carcinoma of stomach	50
7. W. H.	56	M	Carcinoma of stomach	30
8. G. J.	62	M	Carcinoma of stomach	35
9. V. J.	60	F	Carcinoma of stomach	40
10. R. McK.	56	M	Carcinoma of stomach	35
11. A. P.	70	F	Carcinoma of esophagus	25
12. G. P.	62	M	Carcinoma of esophagus	20
13. N. S.	50	F	Carcinoma of esophagus	30
14. W. D.	55	M	Carcinoma of esophagus	40
15. W. T.	55	M	Carcinoma of pancreas	25
16. J. S.	63	F	Carcinoma undetermined site	35
17. A. C.	65	F	Ruptured appendix	10
18. W. M.	72	M	Carcinoma of prostate	40
19. J. H.	59	M	Carcinoma of stomach	35

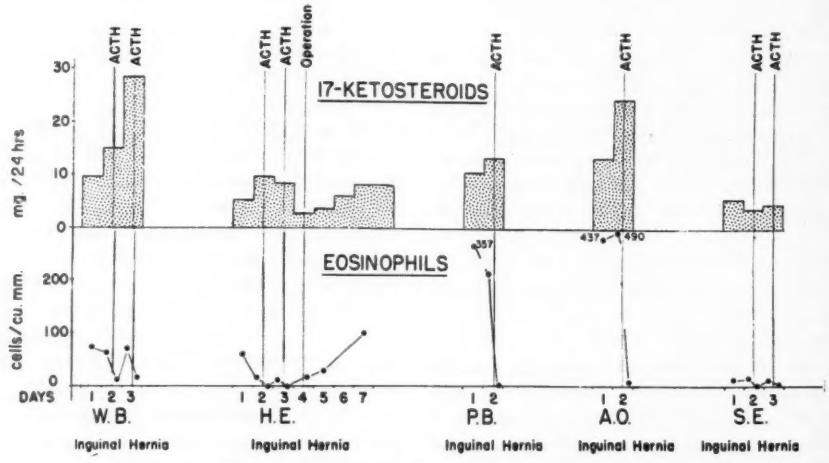

FIG. 1. Adrenocortical reserve in "normals"

17-ketosteroids increased to 20 mg. per 24 hours and remained elevated for the rest of the study. Corticoid excretion (not shown) also increased to 40 mg. From this observation it would appear that a decreased sensitivity of the adrenal cortex to ACTH was present in this subject. This patient also had an uneventful postoperative course.

Patient V. J. exhibited no rise in 17-ketosteroids after ACTH and corticoid analyses (which are not shown here) also revealed no rise after infusion. Following operation no rise occurred in corticoid excretion. Since the eosinophil count was already near zero, this test afforded little additional information. This patient also had an uneventful postoperative course indicating at least moderate adrenocortical activity.

The next illustration (fig. 3) shows the response of four patients with obstructing carcinoma of the esophagus. Despite extreme

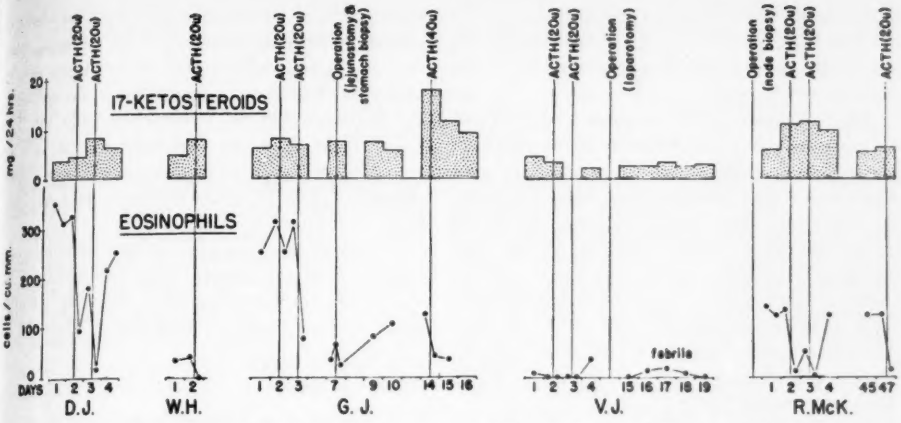

FIG. 2. Adrenocortical reserve in patients with carcinoma of the stomach

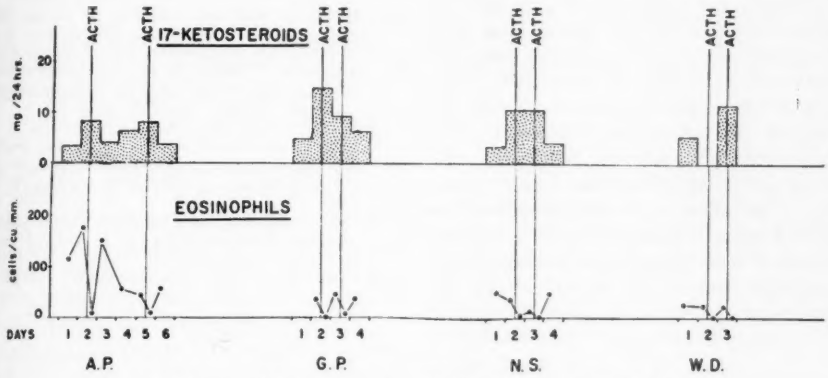

FIG. 3. Adrenocortical reserve in patients with esophageal carcinoma

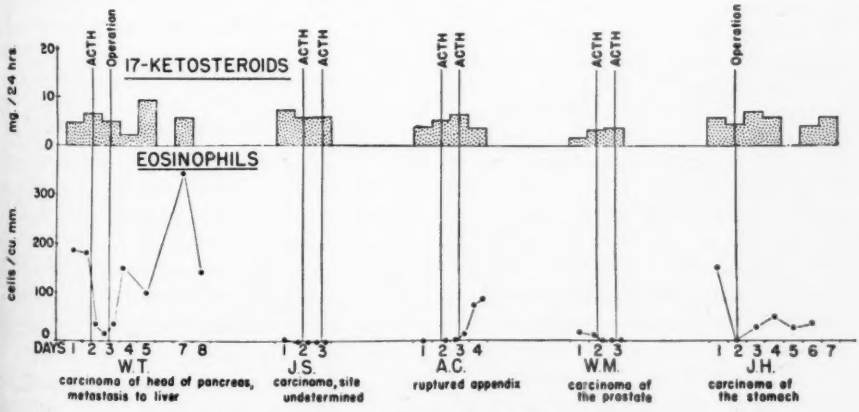

FIG. 4. Adrenocortical reserve in debilitated patients

debility all of this group responded well to ACTH (*e.g.*, patient N. S.). The low control eosinophil counts were due presumably to the stress of their disease.

Figure 4 illustrates the response to ACTH and in some instances the response to operation in patients with debilitating disease which in most cases was a carcinoma of some type. Generally in this group there is only a mild increase in 17-ketosteroid excretion following ACTH. The occasional problem of postoperative adrenocortical insufficiency is encountered in patients such as these and patients V.J. and G. J. Note the characteristic absence of a rise in 17-ketosteroid excretion following operation as shown here by J. S. and W. T.

SUMMARY AND CONCLUSIONS

In summary the intravenous ACTH test has been used in five apparently normal and fourteen markedly debilitated patients to determine the incidence of relative adrenocortical insufficiency in chronically ill surgical patients. In one 68-year-old "normal" individual and in one of the chronically ill subjects there was no increase in the urinary excretion of either corticoids or 17-ketosteroids, presumably indicating a diminished adrenocortical responsiveness. However, both of these subjects had total eosinophil counts which were almost at zero during the control period (indicating at least a degree of adrenocortical activity), and both withstood operation without event. A third subject, who was not given ACTH but whose response to operation was examined, exhibited no increase in the excretion of either corticoids or 17-ketosteroids. Yet the eosinophil count fell to zero and he underwent the operation without difficulty. Thus the total eosinophil count emerges as a useful test.

It is concluded that while a diminished adrenocortical response may be observed at times in chronically ill subjects, these subjects usually survive surgery without replacement therapy.

899 Madison Ave.
Memphis, Tenn.

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PRIMARY ALDOSTERONISM*

ROBERT ALTON PARRISH, JR., M.S., M.D.

Memphis, Tennessee

As early as 1934 an amorphous fraction isolated from adrenal extracts was found to have properties of life maintaining activity. Since that time many adrenal hormones have been isolated and developed for clinical use. However, it was not until 1952 that a specific crystalline component of this amorphous fraction was isolated and characterized. This fraction, now called aldosterone (electrocortin) was discovered by Grundy, Simpson and Tait.[4] Although aldosterone has been available in crystalline form for approximately four years, considerable progress has been made in determining its biologic activities and probable physiologic status in man and experimental animals.

Most of the biologic investigation with the amorphous fractions of adrenal extracts was carried out with the preparations of Kendall and his associates.[16] This amorphous fraction was found to contain about half of the life maintaining activity found in whole adrenal extracts and adrenalectomized dogs could be maintained on 1 to 2 μg. per day. It was found that this fraction would not cause thymic or adrenal atrophy nor would it inhibit growth as effectively as corticosterone.[10] Carbohydrate metabolism was found to be only slightly affected by this fraction. Aldosterone was found to have a supporting action on lactation[9] as well as afford protection against water intoxication[6] and the stress of cold.[15]

In 1954 Simpson, Tait and others announced the chemical structure of electrocortin as the 18-aldehyde of corticosterone.[10] For this structure they proposed the name aldosterone. The main sources of aldosterone have been beef and hog adrenal brei; however, the amount of material produced by these sources is extremely small and the process of extraction expensive. Recently, is studying the urine of nephrotic patients, Luetscher, Neher and Wettstein found amounts of aldosterone which may prove large enough to make certain types of human urine a desirable source of the hormone.[19]

No doubt many patients have been seen with primary aldolsteronism, but in them the correct diagnosis has not been established. It is hoped that this paper may help establish the importance of the syndrome and thereby aid in initiating its cure.

Before describing the condition of primary aldosteronism the biologic properties and probable physiologic actions of aldosterone will be reviewed briefly in order that a better understanding of the syndrome can be acheived.

EFFECTS ON ELECTROLYTE METABOLISM

When the action of aldosterone is compared with that of desoxycorticosterone in adrenalectomized rats, the former is found to be much more potent in causing sodium retention and potassium excretion but is without effect on water excretion. The amount of increased potency over desoxycorticosterone seems to vary with the technique used in the hormone assays; however, even the lower figures rate aldosterone twenty times more potent then desoxycorticosterone.[12]

Notable effects of aldosterone on electrolyte metabolism have been observed not only on kidney function but also on sweat and salivary secretions. It has been shown by Mach, Pawan, Simpson and Tait, that small amounts of aldosterone will depress the salivary sodium–potassium ratio but is without effect on sweat sodium. This depressed ratio has been shown to be due to the decreased sodium content of saliva following the injection of aldosterone.[10] Kekwick, Pawan, Prunty and others, in studying the effect of aldosterone in patients with Addison's disease, found that with dosages in the range of 100 μg. per day maintainence of electrolyte balance and well being could be attained. There was no noticeable influence on water metabolism.[14, 20] Further studies showed that if doses of aldosterone in the range of 1 mg. per day were given

* From the University of Tennessee, Memphis, Tennessee.

to normal and Addisonian subjects some salt and water retention occurred.[21]

EFFECTS ON WATER METABOLISM

In a detailed study of water excretion aldosterone and many other steroids were compared by employing the Kagawa test in rats. Aldosterone was found to have no effect on water excretion even though it caused potassium depletion and sodium retention. Under the same conditions desoxycorticosterone was found to be antidiuretic in proportion to sodium retention and in proportion to dose. Cortisone, corticosterone and hydrocortisone differed in their effects upon both water and electrolyte excretion. They also differed in effect from both desoxycorticosterone and aldosterone.[10] Luetscher and co-workers in studying patients excreting large amounts of endogenously produced aldosterone found no consistent relationship between urinary volume and urinary titers of the hormone; however, an inverse relationship existed between the amounts of aldosterone and sodium excreted.[18]

POSSIBLE ROLE IN EDEMA

Suppression of sodium excretion in the urine is found in connection with the accumulation of edema in cardiac failure, the nephrotic syndrome, toxemia of pregnancy and hepatic cirrhosis. This pattern of impaired sodium excretion occurs in the presence of low, normal or even increased glomerular filtration rates. In all of the above conditions there have been found excess amounts of salt retaining factors similar if not identical to aldosterone.[13] The presence of edema in any of these conditions does not necessarily mean that there will always be excess aldosterone levels present in the urine. The most reliable index for suspecting or predicting high aldosterone excretion seems to be that of a low sodium excretion. The output of aldosterone is increased during dietary sodium restriction in normal men and this increase corresponds to the reduction in urine sodium excretion during the low sodium intake, returning to normal levels as sodium output increases after resumption of a normal diet. Patients with Addison's disease or adrenalectomy do not excrete aldosterone, but it was observed by Luetscher and Axelrad that two patients with hypopituitarism had normal urine levels of aldosterone, suggesting that the secretion of the latter is not dependent on any hormone of the anterior pituitary.[22] Even after hypophysectomy in the dog, aldosterone secretion continues in measurable amounts and is not enhanced by ACTH.[22]

The most important question, and as yet an unanswered one, is that concerning the cause and effect relationship of aldosterone to various diseases in which it is excreted in increased amounts. Increased excretion of aldosterone in urine is well correlated with sodium retention and accumulation of edema in such diseases as cardiac failure, the nephrotic syndrome, hepatic cirrhosis, and toxemia of pregnancy, but edema is not present in some patients spontaneously excreting large amounts of aldosterone from known or presumed adrenal tumors.[19] Therefore, the increased excretion of aldosterone in diseases characterized by the accumulation of edema does not necessarily mean that it is the cause of the edema. On the other hand it may mean that in the presence of pathologic changes caused by the disease aldosterone is produced by adrenal stimulation and then in turn causes the accumulation of edema fluid. Or aldosterone may be present only secondarily in these diseases and may have no direct relationship to the edema formation. In other words, the altered endocrine physiology in such cases may be the result rather that the cause of the disease.

EFFECT ON BLOOD PRESSURE

No available evidence suggests that aldosterone will produce hypertension as will desoxycorticosterone although it will maintain a normal blood pressure in adrenalectomized animals and Addisonian patients.[14, 20, 23]

PRIMARY ALDOSTERONISM

On October 29, 1954, Dr. J. W. Conn described a new clinical syndrome which he proposed to term primary aldosteronism.[2] The patient was a 34-year-old woman with complaints of intermittent spasms, weakness and paralysis of muscles for seven years. Between these attacks the patient felt well. She complained of polyuria and nocturia for many years and was known to be hypertensive for four years. Physical examination revealed a blood pressure of 176/104, well developed musculature and hyperactive reflexes. Laboratory examination revealed hypokalemia, hypernatremia and alkalosis. Urinary

17-ketosteroid and 17-hydroxysteroid excretions were normal but aldosterone assays revealed greatly elevated amounts (more than ten times normal values). Except for a trace of proteinuria and a low fixed urinary specific gravity, urinary function studies were normal. Liver function tests were also within normal range. Sodium and potassium levels of saliva and of sweat revealed greatly depressed sodium and chloride concentrations with abnormally high potassium levels. No significant changes upon abnormal serum values of sodium or potassium nor upon the symptomatology were observed following long continued administration of potassium. When either compound F or ACTH was administered, high 17-hydrocorticoid levels were obtained and sodium diuresis occurred, suggesting that high levels of the latter act as an antagonist to aldosterone, thus reversing the direction in which the sodium ion moves across the cell membrane.[2]

This patient was explored surgically and the right adrenal gland, containing a 4-cm. cortical adenoma, was removed. Bioassay of the tumor revealed large amounts of aldosterone. Multiple biopsies revealed great excess of intracellular sodium with marked decrease of intracellular potassium in skeletal muscle and severe arteriolosclerosis with renal tubular damage on specimens taken from the kidneys. Microscopic evidence of atrophy of the zona fasciculata in the contralateral adrenal suggested the site of aldosterone production, according to Conn. Within ten days following surgery all of the abnormal chemical changes noted prior to operation had returned to normal and have remained so up until this time. The blood pressure returned to normotensive levels and the patient has been asymptomatic.[2]

Several additional cases appear in the literature which are similar if not identical to the syndrome described as primary aldosteronism. Earle and co-workers in 1951 and Wyngaarden and associates in 1954 each described a case of potassium depletion and alkalosis which, according to Conn's interpretation, represent a late stage of primary aldosteronism.[22, 24, 30] Mader and Iseri reported a case in 1954[20] which is practically identical with Conn's case. The only noteworthy difference in this case is the additional finding of hypomagnesemia, the significance of which has not been determined. At surgery an adrenal cortical adenoma was removed.

In 1956, Chalmers, FitzGerald, James and Scarborough[1] reported a case of Conn's syndrome in which a cortical adenoma of the right adrenal was found at surgery. This case differs from Conn's original description in that severe hypertension was present, alkalosis was slight or absent and there was nausea and diarrhea associated with the illness. Removal of the tumor lowered the aldosterone output to subnormal levels and converted a salt plethora at least transiently into a salt depletion.

Crane, Vogel and Richland[5] reported a presumed case of primary aldosteronism in a 32-year-old man who had simple essential hypertension associated with the unusual complaints of dryness of the mouth and intermittent episodes of muscular weakness. The laboratory findings revealed a severe hypokalemia and metabolic alkalosis. Another interesting finding in this case is the greatly increased uropepsin rates. Elevated uropepsin values have been observed in peptic ulcer and other diseases. Since normal values for uropepsin have been obtained in this case, following removal of a small adrenal cortical adenoma, the authors suggest that secretion of pepsinogen by the gastric mucosa may be influenced by aldosterone. In addition to return of normal uropepsin excretions, the symptoms and electrolyte disturbances were relieved by removal of the cortical tumor.

One of the most recent cases is that of Fine and associates in which the symptomatology and renal defects were less intense than in other reported cases but in which the endocrine disorder was complicated by the presence of rheumatic heart disease.[8]

The effects of aldosterone deficiency have been established by Hudson and associates[11] in a report of a patient in whom repeated attacks of cardiac standstill were apparently produced by the effects of spontaneous hyperkalemia on a pre-existing complete atrioventricular heart block. Exhaustive studies suggested that the elevated potassium levels were caused by an isolated defect in adrenocortical function resulting in aldosterone deficiency, as other adrenal steroid production was normal.

DISCUSSION AND CONCLUSIONS

Aldosterone has been isolated from the amorphous fraction of adrenal extract. It has been

crystallized, its formula has been established, and it is now considered to be a true hormone originating most likely in the zona fasciculata of the adrenal cortex. Aldosterone is much more potent than desoxycorticosterone in causing sodium retention and potassium excretion. Aldosterone in dosages of approximately 100 μgm. per day will maintain electrolyte balance and well being in patients with Addison's disease. Aldosterone has been found to have a supporting action on lactation and to give protection against water intoxication and the stress of cold, but is believed to have little if any effect on carbohydrate and protein metabolism. There exists an inverse relationship between the amounts of aldosterone and sodium excreted in the urine. Increased excretion of aldosterone in urine is well correlated with sodium retention and accumulation of edema in such diseases as cardiac failure, the nephrotic syndrome, hepatic cirrhosis, and toxemia of pregnancy, but edema is not present in some patients spontaneously excreting large amounts of aldosterone from known adrenal tumors.

Primary aldosteronism has now been established as a true clinical entity. Since Conn's preliminary report (October 1954) there have been approximately 15 additional cases.[5, 8, 12, 23] Of these cases 11 have been either cured or greatly improved by removal of an adrenal cortical adenoma and one by bilateral adrenalectomy. One case was due to adrenocortical hyperplasia.[23] The three remaining cases were recognized in retrospect, having had the clinical picture and having an adrenal cortical adenoma demonstrated at autopsy.[3]

The characteristic clinical picture of primary aldosteronism consists of periodic muscular, weakness (and sometimes pseudoparalysis), intermittent tetany, paresthesia, hypertension, polyuria, nocturia, polydipsia and absence of edema. That this picture may vary, as in other syndromes, is evident from the above cases. Hudson and associates[11] have shown that hypoaldosteronism may exist as an isolated defect in adrenocortical disorders.

The clinical pictures of hyperaldosteronism and hypoaldosteronism have been established. Although there is much to be known concerning the physiology of aldosterone, it is evident from the information now available that a clearer understanding of the mechanisms of fluid and electrolyte balance is forthcoming.

899 Madison Ave.
Memphis, Tenn.

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A STABLE, SAFE, HIGH CALORIC FAT EMULSION FOR CLINICAL INTRAVENOUS ALIMENTATION*

JOE CAMPBELL, M.D.

Memphis, Tennessee

It has been long recognized that adequate caloric requirements could not be met satisfactorily by currently available intravenous preparations. Many intravenous solutions have been used in an effort to supply needed daily calories in people unable to take oral feedings. Glucose, protein hydrolysates, alcohol and other carbohydrate solutions, currently in use today, do not provide adequate calories in volumes that can be administered safely. For this reason there has been an increasing effort during the past 20 years to provide sufficient intravenous calories using various types of fat emulsions. In general, these emulsions are prepared by high pressure homogenization of a suitable oil, emulsifying agent and water. While aqueous fat emulsions satisfy caloric needs, their administration to human beings has been fraught with a number of undesirable side effects which increase sharply with aging of the substances. The lack of physical and chemical stability of aqueous fat emulsions has prevented their commercial production. Most of them are unsuitable for human use after one month, and, to date, no aqueous emulsion has been acceptable after four months.

It is believed that hydrolysis of aqueous fat emulsions is responsible for their rapid deterioration. To circumvent this problem Dr. D. B. Zilversmit and his associates[4] devised a method of preparing a prehomogenized anhydrous mixture which could be converted to an aqueous fat emulsion of desired concentration by the addition of water or glucose at the time of its use.

At the time of preparation the anhydrous mixture, consisting of soybean phosphatides suspended in anhydrous glycerin and a suitable oil, is bottled, autoclaved, and stored ready for use when needed. This prehomogenized anhydrous concentrate has been shown to be physically stable as evidenced by satisfactory particle size after more than two and one-half years of storage at room temperature and after autoclaving and rapid freezing (if an unsaturated oil is used). The anhydrous preparation is chemically stable as evidenced by the rate of hydrolysis it undergoes with liberation of free fatty acids. The rate of hydrolysis has been shown to be $\frac{1}{10}$ that of an aqueous fat emulsion. The biological stability of the anhydrous mixture has been demonstrated by administration of the stored mixture to human beings. Reaction rates comparable to those with freshly made emulsions have been observed in 156 infusions of the material which had been stored from 4 to 14 months.

Reactions to the fat emulsions are poorly understood. A failure to understand the etiology of the reactions is primarily responsible for lack of acceptance of fat emulsion as a means of supplying calories intravenously. To evaluate the safety and biological acceptability of the anhydrous fat emulsion, three different formulas were studied at the University of Tennessee. After a year of animal experimentation clinical investigations were made. Initially, an emulsion consisting in final dilution of 10 per cent fat, 0.5 per cent phosphatide and 10 per cent glycerin and yielding about 1520 calories per liter was used. A total of 391 infusions was given—60 infusions were 1000 ml. each and the remainder, 500 ml. each. Reactions were quite frequent in the beginning; however, the changing of the fat component of the formula and slowing the rate of infusion lowered the reactions to an acceptable rate. (So that all investigators might have a uniform system of compiling reactions, the Surgeon General's Task Force on Intravenous Fat Emulsion[2] suggested the criteria for reactions which were used in this study.)

Reactions are divided into major and minor types. Major reactions were observed in 4.6 per cent of the infusions and minor reactions, in 7 per cent. Most of the major reactions, however, consisted of intravascular hemolysis to such a degree as to produce demonstrable hemoglobinuria. Although not frequent, such hemolysis makes this emulsion unacceptable for human use.

In an effort to define the etiology of the hemolysis, a study was carried out in which only the glycerin component of the emulsion was singled

* From The University of Tennessee, Memphis, Tennessee.

out for study.[3] Five per cent glucose with 10 per cent glycerin concentration was given intravenously using the same flow rate, and in the same volume as the fat emulsion had been given. This solution produced a high incidence of intravascular hemolysis with resultant hemoglobinuria. When the glycerin concentration was lowered to 5 per cent, no significant hemolysis occurred. The 5 per cent and 10 per cent solutions were given initially at the same infusion rate. Since no hemolysis was noted at this slow rate with the 5 per cent solution, the rate was increased to 200 drops per minute. Still there was no demonstrable intravascular hemolysis. The volume was also varied. Glucose solutions containing 5 per cent glycerin were given rapidly in volumes more than twice that of any solution containing 10 per cent glycerin without production of hemolysis. Thus the concentration of the glycerin is established as the etiologic factor in the production of significant intravascular hemolysis with resultant hemoglobinuria.

Apparently it is the physiologic capacity for clearing the blood of glycerin which is exceeded when solutions containing 10 per cent of this material are administered. Since there is no such violation with a 5 per cent concentration, a greater total daily intake of the latter may be infused than would be safe using 10 per cent glycerin concentration.

The second emulsion formula utilizing a lowered glycerin content in final dilution consisted of 10 per cent fat (cottonseed oil), 0.5 per cent phosphatide, and 5 per cent glycerin. This emulsion yields approximately 1280 calories per liter. One hundred eighty-nine infusions were given, and a 16 per cent reaction rate resulted. Of the total reactions, 94 per cent were chills and fever. These reactions were usually observed late after administration of 200 to 300 ml. of emulsion. Infusions were discontinued at the onset of any reaction and were not resumed. (Jordan and his associates[1] resumed infusions in all but 6 per cent of more than 1000 administrations, although there was a reaction rate of 38 per cent.) Again, using an emulsion containing a concentration of 5 per cent glycerin, hemolysis was eliminated, but the reaction rate with this formula was still higher than would be generally acceptable for routine clinical use.

A third emulsion formula was therefore utilized consisting in final dilution of 5 per cent fat (cottonseed oil), 0.25 per cent phosphatide and 2.5 per cent glycerin. This formula, one-half the concentration of the second one studied, contained approximately 750 calories per liter. Sixty-five infusions of this emulsion were given with only two reactions—both in the same patient who developed chills on two successive days.

As a further clinical trial of the third emulsion formula, infusions in volumes of 2000 ml. per day are being given postoperative patients unable to take oral feedings. Electrolytic and additional fluid needs are being given in a separate infusion. Thus the fat emulsion supplies 1500 calories to which are added the calories contained in the separate infusion administered to supplement fluid and electrolytic needs.

A safe fat emulsion supplying 750 calories per liter has been developed. As more is learned concerning the physiologic mechanisms which must be operative in handling the fat emulsion given intravenously, higher caloric emulsions with acceptable reaction rates will be developed. Then and only then will the caloric requirements which are of paramount importance be met in patients who for one reason or another are dependent on parenteral nutrition.

899 Madison Ave.
Memphis, Tenn.

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SAFETY VALVE ANASTOMOSIS AND DECOMPRESSION IN INTESTINAL SURGERY BY USE OF A T-TUBE*

GEORGE L. CARRINGTON, M.D.

Burlington, North Carolina

The problem of intestinal resection and anastomosis concerns principally two things besides adequate blood supply to the anastomosis: leakage at the suture line and ileus—mechanical and/or paralytic. Avoidance of ileus does much to avoid leakage. The purpose of the T-tube (fig. 1) at the site of anastomosis is to relieve the ileus by decompression and so avoid leakage at the suture line and consequent contamination of the general peritoneal cavity. The area about the tube is rapidly sealed off by a fibrinous exudate and continuous suction allows little chance for a breakthrough into the general peritoneal cavity.

In 1942 the use of a T-tube in four cases of intestinal surgery was reported.[1] In the first case it was used as a safety valve at the site of anastomosis after resection, and in the other three cases it was used for decompression only. The suggestion was made at that time that the procedure might have a larger field of usefulness in resection, particularly in surgery of the left colon. It is the purpose of his paper to report further experience with the procedure.

At first it was employed where the situation was desperate and where we thought other and more conventional procedures would offer less chance of the patient's survival. Recently it has been used more frequently as an elective procedure, particularly in elderly persons who require resection of the sigmoid for diverticulitis or carcinoma.

The first use of the procedure on the left side of the colon was in a 76-year-old woman (AGH no. 30,301) who had been obstructed for over two weeks. Barium enema showed a complete obstruction at the junction of the sigmoid with the rectum. The patient was a frail woman badly crippled by arthritic deformities. She was malnourished and dehydrated from the prolonged obstruction to the lower bowel. She was markedly distended and desperately ill.

At operation a carcinoma of the large bowel just above the peritoneal reflection was found. A colostomy would have been a lifesaving procedure at the time, but a transverse colostomy would have required two subsequent operations. A colostomy in the lower left side would have left an even more complicated situation. A simple resection and primary anastomosis involved the possibility of ileus, strain and leakage at the site of anastomosis in an unprepared gut of a badly debilitated elderly woman. Resection and primary anastomosis were done, using a T-tube as a safety valve to decompress the gut. The operative recovery was so satisfactory that when confronted with similar situations the procedure has been used without hesitation or trepidation and with gratifying results.

Recently the procedure was used with satisfactory results in elective operations on two elderly patients to avoid nasogastric suction. One was a nervous high-strung woman who would not tolerate the indwelling nasal tube. The other was an elderly debilitated person in whom the chances of pneumonia or atelectasis would have been increased by the nasogastric tube. These results indicate that in unobstructed patients nasogastric suction is not necessary in resections involving portions of the left colon when done by this decompressive procedure.

In elective surgery the procedure occupies an intermediate place between exteriorizing operations and direct anastomoses. It saves time for the patient and heals as quickly as the simple undecompressed direct anastomoses. The occurrence of an occasional paralytic ileus is less likely when bowel is decompressed. Surgeons who employ exteriorizing operations can use this procedure with a security that they would not have with direct undecompressed anastomosis. The patient will benefit because it allows wider resection than the exteriorizing procedure when done as an emergency operation for carcinomatous obstruction of the colon.

PROCEDURE

The technic prefered by the writer utilizes one layer of continuous chromic 4-0 thread with a minimum of infolding and one layer of mattressed

* From the Alamance County Hospital.

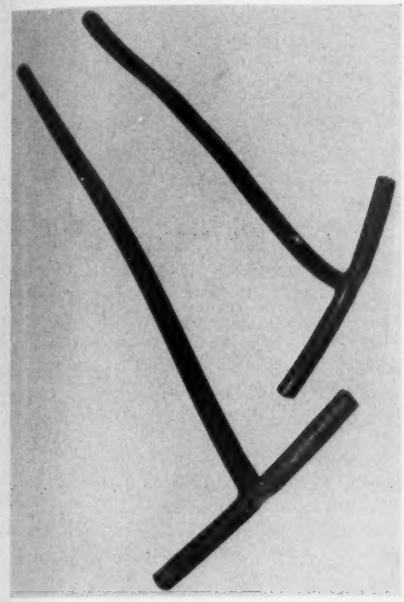

FIG. 1. T-tube showing cut out area opposite long arm to facilitate removal.

cotton or silk. When omentum is available, it is sutured about the T-tube at the site of anastomosis or the long arm of the tube is run through the omentum. If the site of the anastomosis in the gut can be pulled up against the abdominal wall, this procedure is preferred. Nevertheless the results have been good even when omentum was not available and it was not possible to mobilize the site of anastomosis to the abdominal wall (*e.g.*, in the deep pelvis).

A Wappler-Stedman pump is attached to the long arm of the T-tube and suction maintained with 5 to 7½ mm. of mercury negative pressure. A trap bottle is inserted between the T-tube and the pump. The T-tube is kept open by occasionally injecting an ounce or so of water or mineral oil if necessary. One or 2 grams of neomycin may be added to the water.

The tube is removed after ten to twelve days. It is probably not necessary to leave it that long. There has been practically no fecal discharge after removal of the tube, the drainage seldom amounting to as much as a tablespoonful. The wound usually closes in about three days after removal of the tube. The tube is brought out through a stab wound and never through the operative incision.

When the procedure has been used in cases of obstruction of long standing where the bowels have lost the power to contract and are filled with fluid or feces several puncture wounds are made in the small intestine to evacuate it by aspiration. The puncture wounds are usually made longitudinally and closed transversely with cotton mattressed sutures. An obstructed colon filled with feces is irrigated after division and before anastomosis using copious quantities of water until the returned contents are clear. If the procedure is properly conducted, only moderate contamination occurs. Indeed, even without antibiotics, gross cleanliness, minimal trauma to the gut and maintenance of a good blood supply to the anastomosis are probably better than the so-called aseptic methods of anastomosis. Much more trauma is done to tissue by an "aseptic" anastomosis than by the open method of anastomosis.

The abdominal wounds have been closed with a continuous chromic 0 suture in the peritoneum and interrupted rustless steel wire no. 5-0 in the

FIG. 2. Showing patient in bed with arrangement of T-tube and suction apparatus.

fascia. Following Tarana J. G. Dulin's personal demonstration of the usefulness of rustless steel wire in potentially infected wounds at the University of Iowa some twenty years ago, the writer has been a constant believer in its usefulness.

It is probably wise to select a new T-tube for each case. It is essential for the tubing to be firm enough not to collapse under the small amount of suction used (fig. 2). It is also necessary that it be pliable enough for removal without tearing the gut. This latter requirement is facilitated by cutting out a small segment of the short arm at the point just opposite its junction with the long arm of the tubing (fig. 1). The ease with which the short arms of the tube fold when pulled through the partly closed hand with traction on the long arm is a recommended test of pliability.

CASE REPORTS

Case no. 18-283. D. S., a white man aged 23 years, was admitted October 20, 1941, operated on October 21, and discharged November 14; intestinal obstruction of six days' duration; 4½ feet of terminal ileum were resected. Patient recovered.

Case no. 18-523. V. B., a colored woman aged 48 years, was admitted December 7, 1941, operated on December 8 and discharged December 21. String adhesion and volvulus were disclosed. Intestines were evacuated; T-tube decompression was effected. Patient recovered.

Case no. 19-296A. V. B. B., a white man aged 52 years, was admitted June 23, 1942, operated on June 23, and discharged July 15. The ascending colon and part of the transverse colon were resected for annular lesion thought by the pathologist to be tuberculous. An end-to-end anastomosis of the terminal ileum to the transverse colon was made about the T-tube. Operative recovery was achieved.

Case no. 19-440. E. G., a white boy aged 6 years, was admitted and operated on July 25, 1942 for an obstruction due to edema in the terminal ileum and cecum; T-tube decompression was accomplished. Patient recovered and was discharged on August 10.

Case no. 20-320. E. S., a white woman aged 42 years, was admitted January 24, 1943, operated on January 25 for volvulus of the lower ileum with gangrene and perforation. An intestinal resection with T-tube anastomosis was performed. She recovered and was discharged February 12.

Case no. 21-668. I. T. M., a 72-year-old white man, was admitted October 24, 1943, operated on the same date for a strangulated femoral hernia with gangrenous knuckle of gut; decompression with T-tube was done at the site of the gangrenous knuckle and the wound was left open to granulate. The patient recovered and was discharged November 24.

Case no. 22-877. O. A. I., a white man aged 53 years, was admitted on July 15, 1944 and operated on the same date for an intestinal obstruction the cause of which was not determined. T-tube decompression was used. The patient died two days later. Autopsy was not done.

Case no. 30-301. M. H., a 76-year-old white woman, was admitted November 20, 1947 and operated on November 25. She was arthritic with an intestinal obstruction of two weeks' duration. Operation disclosed carcinoma of the lower sigmoid which was resected using T-tube anastomosis. Patient recovered and was discharged December 11.

Case no. 23-835A. J. W., a 6-year-old white boy, was admitted February 7, 1945 and operated on March 2. A resection of the distal colon for megacolon was performed. Patient achieved operative recovery and was discharged March 18.

Case no. 25-419. N. C. S., a white woman aged 49 years, was admitted December 1, 1945 and operated on the same date for intestinal obstruction. Volvulus with gangrenous gut caused by adhesions was disclosed. Three feet of terminal ileum were resected and a T-tube anastomosis was done. The patient recovered and was discharged December 20.

Case no. 27-146. R. G. S., a white man aged 60 years, was admitted October 16, 1946 and operated on October 24. Resection of the distal transverse and descending colon was performed for actinomycosis using T-tube anastomosis. Patient recovered and was discharged November 10.

Case no. 29-230. R. S., a 7-year-old white boy, was admitted May 21, 1947 and operated on the same day for laceration of small gut caused by an accident wound received 26 hours prior to operation. Free feces were in the peritoneal cavity. The gut was closed about a T-tube. Patient recovered and was discharged June 29.

Case no. 35-505. I. S., a 58-year-old white woman, was admitted February 21, 1950 and operated on February 23, for intestinal obstruction due to adenocarcinoma of the sigmoid. The colon was filled with feces. The sigmoid was resected and the colon irrigated with sterile water; the anastomosis was done about a T-tube. Convalescence took place without complication other than minor wound infection. This patient had no preoperative antibiotic preparation of colon. She recovered and was discharged March 9.

Case no. 35-377. M. T., a white woman aged 52

years, was admitted February 6, 1950, operated on February 11 for adenocarcinoma of descending colon with invasion of parietes. Preoperative preparation was with Sulfasuxidine. Operation consisted of resection of descending colon and adjacent invaded tissues. T-tube anastomosis was done. Convalescence was uneventful and the patient was discharged February 23.

Case no. 35-091. L. H. W., a 60-year-old white man, was admitted January 3, 1950 and operated on January 12. No intestinal preparation was done. Diagnosis of carcinoma of the bladder was made by the urologist; on operation the primary growth was found to be adenocarcinoma of the sigmoid that was adherent to and invading the bladder. Resections of the bladder lesion and of the sigmoid using T-tube anastomosis were performed. Postoperative course was uneventful.

Case no. 32-581. G. F. S., a 70-year-old white man, was admitted January 2, 1949 and operated on January 10 for obstructing adenocarcinoma of the rectosigmoid with extension. Resection of the rectosigmoid was done using T-tube anastomosis. Patient made good operative recovery and was discharged on January 27, but was seen six months later with abdominal carcinomatosis.

Case no. 32-544. G. S., a white woman aged 34 years, was admitted December 27, 1948, and operated on January 3, 1949, for adenocarcinoma of the rectosigmoid with extension. Preoperative preparation was made with Sulfasuxidine. The operation consisted of resection of the rectosigmoid and T-tube anastomosis. The patient made a good postoperative recovery and was discharged January 19, but was seen six months later with abdominal carcinomatosis.

Case no. 31-571. M. O., a white woman 62 years old, was admitted July 4, 1948 and operated on July 6, for adenocarcinoma of the descending colon. She was prepared for two days with oral streptomycin and Sulfasuxidine. Operation consisted of resecting the descending colon and T-tube anastomosis. Convalescence was uneventful, the patient recovered and was discharged July 24.

Case no. 37-835. J. S. M., an 82-year-old white man, was admitted December 2, 1950 and operated on December 3 for intestinal obstruction of three days duration with gangrenous loop of small intestine over dome of liver through defect in falciform ligament. Resection of gangrenous gut and T-tube anastomosis were done and the tube removed December 14. The patient remained in the hospital for treatment of cystitis superimposed on prostatic obstruction. He developed phlebothrombosis and died of pulmonary embolus on December 29.

Case no. 37-482. A. F. B., a white woman aged 52 years, was admitted October 17, 1950, operated on October 26. Resection of sigmoid was done because of acute diverticulitis with perforation into mesentery of the sigmoid. Preparation was with Sulfasuxidine. Recovery was uneventful and the patient was discharged November 10.

Case no. 47-292. H. L. E., a 52-year-old white man, was admitted January 1, 1953 and operated on January 20. Resection of sigmoid for diverticulitis and diverticulosis was performed after preparation with Sulfasuxidine. Patient disrupted wound nine days later. This man was obese, had a poor abdominal wall and had previously had several hernia operations. He recovered and was discharged 17 days after disruption, February 14, 1953.

Case no. 49-952. J. O. R., a white man aged 68 years, was admitted April 1, 1957, and operated on April 5. Carcinoma just proximal to splenic flexure of colon was resected. Patient made operative recovery and was discharged April 20.

Case no. 50-412. S. C. V., a white woman aged 71 years, was admitted July 9, 1957, and operated on July 12. After preparation with neomycin resection of sigmoid colon was performed for diverticulitis and diverticulosis. Convalescence was uneventful and patient was discharged August 5.

Case no. 50-091. W. J., a 69-year-old colored man, was admitted October 14, 1957, and operated on October 22. After preparation with neomycin a resection of carcinoma of the colon was performed. Patient recovered and was discharged November 6.

SUMMARY

A method of decompressing the intestine by use of a T-tube is described. Its original usefulness was found in resecting obstructive lesions that had produced marked distention and paralysis of the intestine. It has also been found useful in elective procedures. Summaries of twenty-four cases in which the method has been used are presented.

Piedmont Way at Rainey
Burlington, N. C.

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ARTHROPLASTY OF A METACARPOPHALANGEAL JOINT BY A METAL HINGE*

GEROLD KLEIN, M.D.†

Washington, D. C.

Arthroplasty of damaged joints has always been a challenge in reconstructive surgery. Numerous surgical procedures have been developed but are not wholly satisfactory. The replacement of faulty articulations by half or whole joint transplants often results in failure caused by deviation due to resorption. The success of arthroplasty by replacement of one damaged joint surface with either a metal cap or a full metal or plastic prosthesis is limited almost entirely to ball-valve joints. In other joints this method fails to prevent lateral instability or rotation. The interposition of fascia or plastic material as cushioning between the damaged joint surfaces or as replacement of resected articular surfaces was also found to be an unsatisfactory method of joint reconstruction. Theoretically, satisfactory results could be obtained by a full hinge endoprosthesis.

To explore this idea, a full hinge type metal endoprosthesis was developed as replacement for both articular surfaces with the metal joint anchored to the respective bones by intramedullary stems. Several interphalangeal joints originally referred for amputation were replaced with good results in the immediate postoperative period. Simultaneously one metacarpophalangeal joint was reconstructed by a similar metal hinge endoprosthesis. A three year follow-up of this case is now available and is herein reported.

The patient, a 33-year-old soldier, received a gunshot wound in his left hand in Korea in 1950. In 1953 he was referred for amputation of the fourth finger because of deformity and malfunction. Examination of the left hand revealed a fully functioning thumb. Function was present in the index and fifth fingers, but was restricted in both to the extent that there was no satisfactory grip of the hand. The middle ray‡ was missing. The fourth ray was present but shortened, with the metacarpophalangeal and the proximal interphalangeal joints fixed in full extension (fig. 1). Slight active flexion and extension of the distal phalanx of the fourth ray suggested the presence of the respective tendons. The full thickness skin graft, with which the dorsum of the hand had been reconstructed following the original injury, was intact and not tender. Circulation of the hand was satisfactory and there was no gross sensory deficit. Roentgenograms (fig. 2) revealed the absence of the third ray and destruction of the metacarpophalangeal joint of the fourth ray with absence of the head of the fourth metacarpal. The patient volunteered for an attempt to restore function of the fourth ray by reconstruction of the destroyed metacarpophalangeal joint with a metal hinge endoprosthesis as an alternative to the originally planned amputation.

In addition to constructing a new joint, the length of the partially destroyed metacarpal had to be restored in order to produce a functioning hand. Therefore the prosthesis used in the interphalangeal joints was changed by lengthening the proximal half.

The prosthesis (fig. 3) was fabricated of stainless steel. It consisted of two half-joints with triangular intramedullary stems which are inserted separately into the respective intramedullary canals. Rotation is prevented by horizontal fins on either side of the base of the intramedullary stems where they join the hubs of the joint. Extraction or sinking-in of the half-joints is prevented by staples, with one prong inserted into the hub and the other prong inserted through the cortex into a hole in the intramedullary stem. After insertion the two parts of the prosthesis are joined to a simple hinge joint by a half-threaded screw and nut with a special mechanism to prevent loosening

* This work was made possible in the United States Air Force Hospital, Wiesbaden, Germany, through the collaboration of the Chief of the Orthopedic Service, Lt. Col. Earl W. Brannon, presently at Lackland Air Force Base, San Antonio, Texas. The follow-up examination was facilitated by the courtesy of the United States Army Medical Corps.

† From Garfield Memorial Hospital, Washington 1, D. C.

‡ Ray designates the entire finger unit including phalanges and corresponding metacarpal.

FIG. 1

FIG. 2

Preoperatively the muscle system of the left hand was strengthened by intensive physiotherapy. On November 16, 1953, capsulotomy of the proximal interphalangeal joint of the fourth ray was performed and resulted in active 60-degree flexion of the joint.

On December 21, 1953, the metacarpophalangeal joint was exposed through a longitudinal incision in the dorsum of the hand. The metacarpal head was found to be absent and the bone stump sclerotic and attached to the base of the proximal phalanx by dense fibrosis. No synovia was encountered. The bone stump of the metacarpal was separated from the base of the proximal phalanx and freshened at its distal end by a bone saw. The sclerosed intramedullary canal was prepared with a reamer and the intramedullary stem of the larger part of the prosthesis inserted into the excavation. An excellent fixation in the metacarpal was obtained. Therefore, it was thought at the time of surgery that the staples planned in the original design as additional fixation were not necessary.

The base of the proximal phalanx was prepared in the same way and the distal half of the prosthesis inserted and additionally fixed with two staples, since the fixation by the intramedullary stem did not seem to be sufficient. The two half-joints of the prosthesis were then connected with a screw and nut (fig. 4). The extensor mechanism, which had been retracted during the operation, was placed in anatomical position and the skin sutured. The passive motion test revealed full flexion and extension in the newly created fourth metacarpophalangel joint. During the postoperative course the incision healed per primam and with intensive physiotherapy the patient gained 65-degree active motion in the reconstructed joint.

A postoperative roentgenogram (fig. 5) revealed the fourth metacarpophalangeal joint reconstructed by a metal hinge prosthesis anchored to the residual metacarpal and to the proximal phalanx by intramedullary stems. The distal part of the joint was shown to be additionally fixed with two staples. The missing part of the fourth metacarpal had been replaced by the lengthened hub of the proximal half-joint.

On January 25, 1954, approximately four weeks following the insertion of the prosthesis, the patient's hand was subjected to excessive activity which resulted in loosening of the staples and deviation of the basal phalanx. Therefore the staples were removed and the distal half-joint of the prosthesis reinserted. This time perfect

FIG. 3

FIG. 4

FIG. 5

stability was obtained in the basal phalanx also by the intramedullary stem alone, and additional fixation by staples therefore seemed unnecessary. During this operation it was noted that a smooth collagenous membrane had formed around the hinge part of the prosthesis and no adhesions to the fully functioning hinge were seen. A small amount of clear yellowish fluid resembling normal synovial fluid was found between the newly formed membrane and the clean steel hinge. Following this operation the patient again regained the same function as after the original insertion (fig. 6).

Examination four months later revealed active, painless, 80-degree motion in the prosthetic metacarpophalangeal joint of the fourth digit and active 65-degree motion in its proximal interphalangeal joint. Good strength and excellent function had been restored to the hand, provided mainly by the thumb and reconstructed digit, and the patient was therefore able to carry on his former duty as a military policeman without difficulty.

Nine months after the original insertion of the prosthesis the patient reported with pain and limitation of motion in the prosthetic joint. Examination revealed the screw in the hinge joint to be loose. In another operative procedure this screw was replaced on September 29, 1954. Again normal synovial fluid was found around the prosthesis. Postoperatively the patient again regained the same function as after the original insertion.

A follow-up examination was performed on February 28, 1957, three years after the reconstruction. Inspection of the hand (fig. 7) revealed that shortening of the fourth ray had taken place. The proximal interphalangeal joint showed a 45-degree range of painless motion, meaning a loss of 15 degrees in comparison with the immediate postoperative result. The prosthetic metacarpophalangeal joint showed a range of 15 degrees of painless active motion, indicating a loss of 50 degrees in comparison with the postoperative result. On flexion there was also a medial deviation of the fourth finger noted, caused by the insuffi-

FIG. 6

FIG. 7

FIG. 8

ciently channeled extensor tendon which slipped medial to the prosthetic joint on flexion.

The cause of this cosmetic and functional deterioration was found in a roentgenogram (fig. 8) which revealed the prosthesis still connecting the fourth metacarpal to the basal phalanx of the fourth finger. However, resorption had taken place at the bone-metal contact, and both half-joints had sunk into the adjacent parts of the respective intramedullary canals, resulting in the protrusion of the proximal intramedullary stem through the metacarpocarpal joint.

In spite of these cosmetic, functional and structural defects, the over-all function and strength in the left hand was found to be sufficient to permit the patient to perform active duty as chief clerk of his military unit, involving considerable daily typing without ill effect. The patient himself is extremely well satisfied with the result (fig. 9).

Evaluation of this case reveals certain shortcomings in the construction of the prosthesis. This conclusion is supported by similar deterioration which developed also in some of the interphalangeal prosthesis which had shown excellent results in the immediate postoperative period.

The main defect is the sinking-in of the intramedullary stems caused by resorption at the metal-bone contact in conjunction with muscle action. This difficulty had been foreseen at the original construction and an attempt was made to eliminate it by extramedullary fixation with the above described staples. In retrospect it has to be considered an error in judgment to rely solely on a tightly fitting intramedullary stem without using all the staples at insertion.

The second defect was seen in the construction of the original staples which could not be inserted securely enough to prevent loosening.

FIG. 9

Recognition of these defects was the basis for redesigning this prosthesis with special emphasis on additional extra medullary fixation by newly designed staples which cannot loosen after their insertion. Also, several types of expanding internal fixation and a combination metal-plastic stem are at present under evaluation in order to meet the ultimate goal of any internal fixation, that is, to obtain absolute stability which remains permanent in spite of bone resorption and muscle action.

SUMMARY

A new type of arthroplasty of a traumatized metacarpophalangeal joint by a metal hinge endoprosthesis with a three year follow-up is presented and its value and defects discussed.

Garfield Memorial Hospital
Washington 1, D. C.

A METHOD OF MAINTAINING CEREBRAL CIRCULATION WHILE RESECTING LESIONS OF THE CAROTID AND INNOMINATE ARTERIES: AN EXPERIMENTAL STUDY

L. R. SOLTERO, M.D., AND S. DONALD GREENBERG, M.D.*

Houston, Texas

Aneurysm, tumor, arteriovenous fistula and arteriosclerotic occlusive lesions occasionally involve the innominate and carotid arteries. Recent developments in vascular surgery have permitted excision and restoration of blood flow for such lesions occurring in other segments of the arterial system; however, similar surgical treatment of such lesions involving the innominate or carotid arteries imposes special problems owing to their vital function in supplying blood to the brain. The necessity for temporary arrest of circulation through these vessels during performance of the procedure even for brief periods may produce serious ischemic damage to the brain, which is one of the most sensitive organs to acute anoxia. Although the reported incidence of such complications following ligation of the carotid artery has been somewhat variable, it is generally agreed to be relatively high with figures ranging between 25 and 70 per cent.[3, 9, 14, 19] A relatively high incidence of such complications has also been observed even after temporary interruption of circulation through these vessels. This is well demonstrated by the occurrence of transient or permanent neurologic changes in four of seven recently reported cases of aneurysm or injury of the innominate or common carotid arteries treated by resection and restoration of arterial continuity.[8, 10-12, 16-18] The occurrence of ischemic damage in these cases could not be correlated with the duration of circulatory arrest, and the various tests of adequacy of collateral circulation have not proved entirely reliable as exemplified by the occurrence of hemiplegia after the test had indicated an adequate collateral circulation[2, 4, 7-9, 13, 15] Similarly, various methods of increasing collateral circulation have been proposed, but these too have not been found entirely dependable.

In light of these considerations and particularly in view of the unpredictable but frequent occurrence of ischemic brain damage following excisional therapy of lesions of the innominate and carotid arteries, it would appear highly desirable to employ methods that provide effective protection against the development of such complications both during and after operation. Excision and restoration of arterial continuity by end-to-end anastomosis or by the insertion of a suitable substitute is the obvious procedure of choice, both because of the curative nature of this therapy and its provision for permanent cerebral circulation. The problem at the present time is protection of the brain against ischemic damage consequent to temporary arrest of innominate or carotid circulation during the performance of this procedure. Two methods have been proposed, hypothermia and the use of a temporary shunt; however, these have not always been successful in the prevention of ischemic brain damage.[1, 5, 6] A review of these methods reveals that their greatest possible improvement would be in the development and construction of a temporary shunt that could be quickly inserted and would maintain a reasonably normal blood flow distal to the field of operation. This report is concerned with the development of such a shunt, and since it maintains circulation experimentally, it may be of considerable benefit in the clinical treatment of lesions requiring maintenance of circulation during operation.

MATERIAL

The special equipment used in the experiment consisted of a shunt and two specially designed partial occluding clamps employed during insertion and removal of the shunt. Although this equipment was employed experimentally, vessels comparable in size to human innominate and carotid arteries were used in the experiment; consequently, a detailed description of the instruments would appear indicated.

The shunt consisted of two tooled lucite cannulae and a Tygon connecting tube. The cannulas were made in the instrument shop according to the specifications outlined in figure 1. The

* From the Cora and Webb Mading Department of Surgery, Baylor University College of Medicine, Houston, Texas.

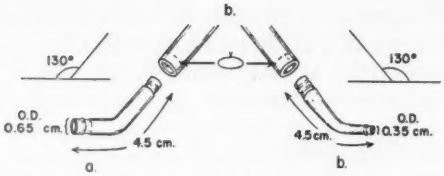

FIG. 1. Diagram of various parts of shunt showing certain specific dimensions.

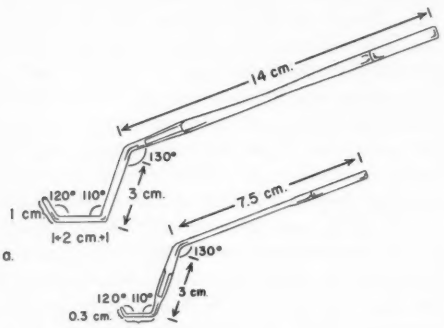

FIG. 2. Diagram of partial occluding clamps showing their various dimensions.

inside diameter of the shunt approximates that of the vessels bypassed; consequently, a normal blood flow is permitted distal to the field of operation. The angulation in the cannulas facilitates both the placing of the connecting tube outside the operative field and unhindered blood flow through the system. The lumen of the distal cannula is tapered to accommodate the normally smaller diameter of the distal arterial segment. The proximal ends of the cannulas have two or more flanges to insure a secure fitting between cannula and connecting tube. Two tourniquets for the control of the host vessels and for holding the shunt in place were made of two lucite pegs through which holes were bored to accommodate a doubled umbilical tape ligature.

In order that circulation might not be interrupted during insertion of the shunt, the involved arteries should be occluded only partially while making and closing the arteriotomies into which the cannulas are inserted. Partial occluding clamps were designed for this purpose with thin blades which provide maximum exposure of the arteriotomy site and minimal occlusion of the vessel (fig. 3). A distal interlocking tooth was developed on the tip of the blades to prevent scissoring which tends to occur with such thin blades.

METHOD OF STUDY

The abdominal aorta and iliac arteries of medium sized dogs correspond in size to the innominate and common carotid arteries in man; consequently, dogs served as excellent experimental animals in which to study the adequacy of the shunt in maintaining distal circulation. The abdominal aorta and left common iliac artery of heparinized dogs were exposed under Pentothal anesthesia and the partial occluding clamps were applied anteriorly to each of these arteries (fig. 4). Arteriotomies slightly larger than the diameter of the cannula to be inserted were made and held open by a suture of 5-0 arterial silk placed on each side of both incisions. The arteries were then completely occluded above and below each incision and the cannulas rapidly inserted following which the clamps completely occluding the arteries were removed. Bleeding around the cannulas was controlled by a tourniquet which surrounded the artery and cannula and consisted of umbilical tape drawn through a lucite peg described above. After insertion of the cannulas a segment of iliac artery being bypassed was excised

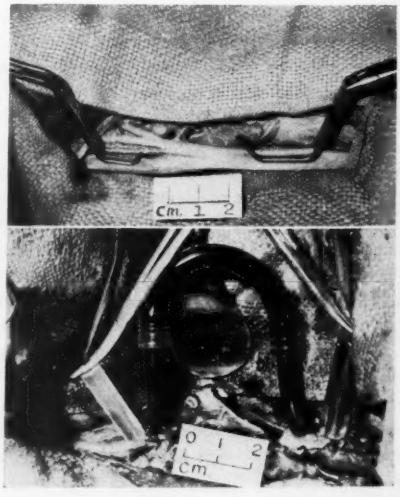

FIG. 3 (*top*). Photograph taken at operation showing the two partially occluding clamps applied to the aorta above and common iliac below.

FIG. 4 (*bottom*). Photograph taken at operation showing functioning shunt in place.

and replaced by a fresh homograft in 10 dogs. After insertion of the grafts, the cannulas were removed and hemorrhage controlled by the simultaneous reapplication of the partial occluding clamps described previously. The arteriotomies were then repaired using fine atraumatic arterial silk. The average total time for shunt insertion and removal was three minutes in these experiments. Blood pressure was measured in the femoral artery distal to the field of operation through the experiment in all animals.

RESULTS

The shunt could be effectively inserted in all ten dogs and as previously indicated an average of ninety seconds was required both for insertion and removal of the shunt. Blood pressure taken in the femoral artery distal to the region of operation was essentially unchanged after insertion of the shunt indicating an approximately normal blood flow through the tube (table 1). The application of the partially occluding clamps did not significantly reduce the femoral artery blood pressure distal to the region of occlusion although sufficient partial occlusion had to be obtained for adequate arteriotomy (table 2). Consequent to these two factors of the experiment, circulation was interrupted for only ninety seconds at any one time during resection of a segment of iliac artery and replacement by homograft. Postmortem examination of the region of operation four months after operation showed normal healing at the site of both arteriotomies and the graft operation. Arterial injury by the cannulas was not evident in any of the specimens.

TABLE 1

Femoral artery blood pressure before and after insertion of shunt into proximal aorta and common iliac arteries in five dogs

Dog No.	Before	After
1	128	128
2	142	140
3	165	158
4	135	136
5	145	145

SUMMARY AND CONCLUSIONS

The principal problem in the application of excision and restoration of blood flow to lesions of the innominate and common carotid arteries is maintenance of cerebral circulation during operation. A review of the various approaches to this problem indicates that greatest improvement may be obtained through the use of a temporary bypass shunt. A shunt consisting of two tooled lucite cannulas and Tygon connecting tubing was constructed. By using specially designed partial occluding clamps, it could be inserted in ninety seconds without significant disturbance in blood flow during the resection of a segment of iliac artery and the insertion of a homograft in ten dogs. These constant satisfactory experimental results indicate the reliable nature of the shunt and suggest its application in clinical problems.

TABLE 2

A summary of blood pressure taken in the femoral arteries of 20 dogs with partial and complete aortic and iliac occlusion*

Dog No.	Femoral Artery B.P. (Mean)	Occluded Aorta	Occluded Common Iliac	Partially Occluded Aorta	Partially Occluded C. Iliac	Partially Occluded Aorta and C. Iliac	Fall in Mean Blood Pressure
1	128	23	41	124	122	121	7
2	142	39	45	142	142	138	4
3	165	20	45	164	162	160	5
4	135	35	45	135	135	135	0
5	145	23	35	143	143	143	2
6	160	35	100	160	160	156	4
7	149	40	60	149	140	140	9
8	155	35	60	154	154	151	4
9	145	25	45	145	143	142	3
10	130	20	45	130	126	123	7

* Partial occlusion was produced by the partial occluding clamps.

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PECTUS EXCAVATUM*

PAUL C. ADKINS, M.D., AND BRIAN BLADES, M.D.

Washington, D. C.

The chest deformity generally termed pectus excavatum has been recognized as an entity for three and one-half centuries.[3] However, it has been less than fifty years since surgical correction was first thought to be feasible. The evolution of the surgical attack on this deformity parallels other developments in the field of thoracic surgery. The first attempt at operative intervention for relief of a pectus excavatum was made by Meyer in 1911. During the subsequent decade, Sauerbruch, Lexer and Alexander[13] were successful in correcting this deformity. Operations were, however, reserved for those patients with severe sternal depression and impairment of vital functions. In those patients with a less marked deformity, surgical intervention was considered too risky to be justifiable.

With the advent of the modern techniques of anesthesia, blood replacement and other refinements, the surgical attack on pectus excavatum has become as safe as most other elective operative procedures.

The exact etiology of this deformity remains an enigma. Most authors are in agreement that an abnormal pull is exerted by the diaphragm on the lower portion of the sternum.[3, 9, 12] The true role of the substernal ligament in the production of a funnel chest remains unsolved. Although some authors emphasize the importance of hypertrophy or contraction of the substernal ligament in exerting traction on the lower portion of the sternum,[3, 9, 11, 12, 15] it has been our experience that hypertrophy of this ligament is infrequently encountered in operations for pectus excavatum.[17]

From a practical standpoint, a pertinent question is why some of these deformities seen in young children will progress during subsequent years, while others remain static or become even less obvious. Another paradox, first observed by Brodkin,[2] is the failure to demonstrate a relationship in older children and adults between the depth of the sternal depression and the severity of cardio-respiratory symptoms associated with the deformity. These and many other questions concerning the etiology and natural history of pectus excavatum remain as yet unanswered.

SYMPTOMS

It has been our impression that the symptoms produced by a pectus excavatum deformity are somewhat difficult to evaluate. Rather close questioning may be necessary in order to elucidate some of the latent symptoms which may be present. Although when first questioned, patients may deny difficulties referable to the deformity, closer interrogation may reveal that they have never been able to keep up with their contemporaries in work or play. Many of them have been subjected to frequent respiratory infections which they were unable to throw off for long periods of time. It is of interest that at least six of the younger children whom we have seen have been treated for long periods by their pediatricians for "allergic or asthmatic bronchitis. This was manifested by frequent respiratory infections with severe cough and wheezing.

Deformity of the chest wall and reduction in the anterior-posterior diameter of the mediastinum may cause considerable interference with the respiratory or circulatory mechanism. There may be marked reduction in maximum breathing capacity, reduction in vital capacity and an inadequate cough mechanism. In addition, compression or rotation of the heart and great vessels may go so far as to lead to congestive failure.[16] We have seen four adults with this deformity who had rather marked cardio-respiratory symptoms as a result of mechanical displacement of the mediastinal contents.

PHYSICAL FINDINGS

In all patients we have seen with a pectus excavatum, the depression was in the lower portion of the sternum and adjacent costal cartilages. In some instances this deformity may be markedly asymmetrical, involving the costal margins or costal cartilages more on one side than the

* From the Department of Surgery, The George Washington University School of Medicine, Washington, D. C.

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other. In the majority of cases the xyphoid was in an abnormal position, being pointed either anteriorly or posteriorly. There may be marked flaring of the costal margins accompanying this deformity. In addition to the depression of the sternum and costal cartilages, the majority of patients seen had some degree of dorsal kyphosis with slumping of the shoulders and protuberance of the abdomen. This generally increased the apparent degree of deformity of the chest. If these skeletal changes have been present for any length of time, as in teen-agers or adults, there is usually accompanying tightness or shortening of the pectoral, the scalene and the trapezius muscles. We believe that this muscular pull is an important consideration in the postoperative period and must be overcome in order to obtain a good cosmetic result.

The cardiac abnormalities accompanying a pectus excavatum have been described in detail by others.[4, 7, 15] In our series, the majority of patients had an audible murmur over the precordium. Subsequent investigations, including cardiac catheterizations in some cases, failed to reveal any intrinsic cardiac abnormalities. Radiological abnormalities of the cardiac silhouette were present in nearly all patients. The most common finding was a shift or displacement of the cardiac shadow to the left side. In no instance have we seen a shift of the heart to the right side. Occasionally, there may be no shift but merely an increase in the transverse diameter of the heart.

Radiologically, all cases have shown some degree of sternal depression on the lateral chest film. In general, the degree of depression and diminution of the anterior-posterior diameter of the mediastinum correlated with the physical appearance of the deformity. With the exception of five adults, there appeared to be little correlation between the degree of deformity and the severity of symptoms, either by physical examination or by radiological findings.

INDICATIONS FOR OPERATION

In those patients with a minimal amount of depression of the sternum, and no symptoms which could be attributed to a pectus excavatum deformity, surgical correction is not advised. Simple postural training may be of value in such instances. Those cases with more than a slight degree of depression are considered to be candidates for surgical correction. The indications for surgical intervention fall into two categories. The first is to prevent or remedy cardiopulmonary difficulties as a result of compression of the mediastinum by the sternal depression. Although symptoms may be minimal during childhood, continued compression of the mediastinum during the growth period may result in manifest symptomatology in later years. At that time surgical correction may be more difficult than if undertaken during childhood or adolescence.

The second indication for surgical correction of a pectus excavatum is for cosmetic purposes. As is well known, the presence of a deformity or depression of an anterior chest wall may be a source of considerable embarrassment to an adolescent or young adult. Even in the absence of definite cardio-respiratory symptoms, surgical correction is felt to be fully justified for cosmetic and psychological reasons.

SURGICAL TECHNIQUES

There are two types of operative procedures available for correction of a pectus excavatum deformity. The first is the relatively simple operation first advocated by Brown,[3] and consists primarily of excision of the xyphoid cartilage and division of the substernal ligament attaching the under-surface of the sternum to the diaphragm. This operation has the advantage of being short and relatively atraumatic. It is our opinion, however, that this procedure is of little value unless it is performed prior to the age of one year, and optimally between the ages of three and six months. At this time the chest wall retains a considerable amount of resilience, and a good result may be anticipated, particularly if there is pronounced paradoxical motion of the depressed segment of the sternum.[8] This simple operation may obviate the necessity of a subsequent radical operation, or if not completely successful cosmetically, may make a subsequent operation less extensive. The value of simple division of the substernal ligament after the patient has reached the age of one year is highly questionable. The results have not been satisfactory and a subsequent correction is almost invariably needed.

It is our belief that infants between the age of one and three years should not be subjected to the more radical type of operative correction of the pectus excavatum deformity. Although they

FIG. 1 (*Top*). Preoperative photograph of 28-year-old female with severe pectus excavatum deformity. The patient had marked exertional dyspnea. (*Bottom*). Postoperative photograph of same patient.

are able to tolerate the operation itself rather well, infants in this age group seldom are able to cooperate in the immediate postoperative period and are much more liable to get into respiratory difficulty as a result of inability to cough and keep a clear tracheobronchial tree. It has been our policy in recent years therefore, to defer operation if possible on children who had passed the first year of age, until they were at least three years old. Probably the optimum age for operation for these deformities is between three and five years. At this time the operation is well tolerated, the children are usually able to cooperate to some extent in the postoperative period, and reconstruction of the anterior chest wall is less formidable than in later years.

OPERATIVE TECHNIQUE

There is little need to describe the technique of excision of the xyphoid and division of the substernal tendon.[3, 9, 12] This has been well

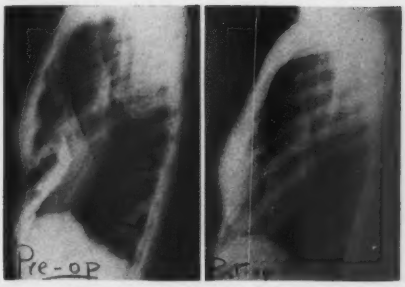

FIG. 2. Preoperative and postoperative x-rays of same patient as is shown in figure 1.

outlined by previous authors. There is little agreement however, about the details of the more radical operations for correction of the deformity. There are two principles which must be observed: First, division of the substernal ligament and second, resection of the costal cartilages and osteotomy of the sternum. Regarding actual correction of the deformity, there have been numerous techniques described which are designed to obtain and maintain a normal position of the sternum. These techniques include the use of wire traction,[3, 9, 10] removal and reversal of the depressed portion of the sternum,[14] various types of wedge osteotomy for plastic reconstruction,[2, 8, 12, 16, 17] and the use of a homologous rib graft as a strut.[1, 5, 6] Each deformity presents an individual problem and one cannot rigidly adhere to a single operative technique for correction of the depression.

We have now abandoned a midline vertical incision which was previously employed, in favor of a bilateral submammary approach. It is believed that the cosmetic result with this type of incision is superior to the vertical scar, particularly in females. The exposure afforded by this incision is equally as good as that of the vertical incision. It offers the additional advantage of the easy access to the costal margins, which may need some tailoring, since there is a tendency in some patients toward excessive prominence of these margins.

All operations are performed under general endotracheal anesthesia in the event that the pleural cavity is accidently entered. A bilateral submammary incision is made and the skin and subcutaneous fat are reflected upward and downward, superficial to the pectoralis and rectus muscles. The xyphoid is freed, grasped and excised. The mediastinal attachments to the

FIG. 3. Lateral chest film of 5-year-old male showing homologous rib strut beneath sternum after correction of pectus excavatum.

FIG. 4 (*Left*). Preoperative lateral chest film of 6-year-old female. Note depression of sternum and displacement of posterior cardiac border. (*Right*) Same patient, 5 months postoperatively.

under-surface of the sternum including the substernal ligament are then divided. In our experience the substernal ligament has rarely been found to be hypertrophied. In addition, the muscular attachments to the costal margins may be divided. When the entire under-surface of the depressed portion of the sternum has been freed from the mediastinum, an over-all evaluation of the extent of the deformity is made. Resections of the costal cartilages adjoining the depressed portion of the sternum are then carried out removing a two to three centimeter segment of each involved cartilage. We prefer not to reflect the pectoralis major and minor muscles from the rib cage in order to obtain exposure of the cartilages, but merely to split these muscles at the appropriate level. It is believed that splitting the muscle fibers is less traumatic than reflecting the entire muscle, affords adequate exposure of the cartilage, and does not interfere with the final cosmetic result. It is usually necessary to resect three or four costal cartilages on each side to obtain adequate mobility for elevation of the sternum.

Following this, some type of sternal fracture is performed. This is usually a transverse fracture of the sternum at the upper end of the depression. A vertical extension as a T-fracture or wedge osteotomy of the sternum may be necessary to obtain adequate elevation. It has been our experience that some degree of over-correction of the depression is desirable for a good cosmetic result. To obtain this it has frequently been necessary to insert a strut beneath the sternum to maintain it in an elevated position. This technique was first described by Dailey[5, 6] and has been most satisfactory to us. Although we have had some experience with artificial struts, we have employed a homologous rib graft for a strut in twelve instances with gratifying results. The ribs have been obtained from our bone bank and have been preserved in a deep freeze under sterile conditions. The rib strut is usually sutured in place with chromic catgut sutures passed around the adjacent rib and through a notch in the rib itself. In no instance has a strut become loose or displaced.

Prior to closure of the wound a soft rubber tissue drain is inserted in the mediastinum and brought out through a stab wound immediately below the incision. A dry dressing is applied and no form of external traction is utilized with this technique.

Should a rent in the pleura occur during the operative procedure and be recognized, a catheter is placed in the pleural cavity on the appropriate side and attached to water-seal drainage. In all cases a postoperative chest roentgenogram is taken in the operating room at the conclusion of the procedure. If a previously unrecognized pneumothorax is present, a chest catheter is inserted prior to sending the patient to the recovery room.

The postoperative care consists primarily of keeping a clear tracheobronchial tree. Chest catheters which may have been placed in the pleural cavity are removed as soon as there is radiological evidence of full re-expansion of the lungs. The soft rubber tissue drains are usually removed by the third or fourth postoperative

day and little specific care is needed following that. The patients are allowed to be ambulatory by the fourth or fifth postoperative day.

In the majority of instances after successful correction of the sternal depression, patients still have a residual dorsal kyphosis, slumping of the shoulders and protuberance of the abdomen. It is our policy to start these patients as soon as possible on postural training and remedial exercises which are supervised by the Department of Physical Medicine. In those patients old enough to follow instructions, this rehabilitation can be started at the end of the first week. In younger children it must be deferred until they are old enough to understand. The exercises consist primarily of postural training and stretching of the pectorals, the trapezius, the scalenes, and the abdominal muscles. It is gratifying to see the amount of additional cosmetic improvement which may be accomplished by this type of training.

It has been our policy to advise postoperative patients to abstain from any strenuous activities for a period of two months. This is to prevent any accidental trauma to the chest wall during the period of healing.

In those patients subjected to plastic revision of the sternum and costal cartilages without use of a rib strut, there has been no trouble with wound healing. In four cases in which a strut had been employed, the strut was subsequently removed because of a persistant draining sinus. These struts were removed without difficulty one to three months postoperatively. In only one instance did this interfere with the over-all cosmetic result. In all others in which a strut was employed, there was radiological evidence of a gradual absorption of the bone graft over periods of eight to ten months.

SUMMARY

1. The advisability of surgical correction of a pectus excavatum deformity of the chest is now well established.

2. The indications and optimum timing of operative intervention are given.

3. A bilateral submammary approach is advocated instead of a midline incision over the sternum.

4. The use of a homologous rib graft as a strut to hold the sternum elevated has been found to be quite satisfactory in severe deformities.

5. The early institution of exercises in the postoperative period to correct faulty posture and overcome muscular tightness is believed to be of considerable value.

901 23rd St., N. W.
Washington, D. C.

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VOLVULUS OF THE COLON

ROBERT W. BUXTON, M.D.*

Baltimore, Maryland

Volvulus is a twisting of the intestine causing obstruction. It combines simple obstruction with twisting of the bowel and mesentery and the immediate danger of strangulation and perforation. Its high reported mortality rate attests to its surgical importance. Volvulus of the large intestine is an uncommon incident in the experience of many physicians.[10] It accounts for less than 5 per cent of the instances of intestinal obstruction as a whole, and less than 10 per cent of the obstructions of the colon.[4] Volvulus of the sigmoid is the most common strangulating obstruction of the colon; it is exceeded only by carcinoma as a cause of acute obstruction of the large bowel. It occurs more than twice as often as volvulus of the right colon.

The current management of volvulus of the sigmoid colon has its advocates of nonoperative treatment[1] and, in these instances, has aroused some controversy; many surgeons are unwilling to accept this measure as standard and definitive because of the inability to determine the presence of strangulation necrosis.[3, 10] Evaluation of either form of therapy has been difficult since most reported series of cases has not been sufficiently large enough to warrant valid conclusions.

The symptoms produced by the volvulus are commonly dramatic and severe. Associated states and lesions may be overlooked or remain unrecognized for a considerable period because of concentration upon the presenting picture. Because of this incidence of associated disease,[14] in every patient with volvulus of the cecum or sigmoid colon complete studies are essential to exclude the presence of an extrinsic or intrinsic lesion.[6]

In order for volvulus to occur, several predisposing factors must exist:

1. A long and freely movable colon must be present. This may be a developmental variant,[10] and may result from a congenital abnormality or exist because of chronic constipation or an obstructing lesion beyond the point of torsion.

2. The mesocolon must be absent or unusually long.

3. The fixed points of the involved loop of bowel must lie closely together. Thus, volvulus of the transverse colon is an exceedingly rare lesion despite the mobility of this segment and the length of its mesentery because of the wide separation of its fixed attachments.

Volvulus of the colon represents a closed loop obstruction and much of the pathologic change in the loop results from the accumulation of gas and fluid. As obstruction persists, increased peristalsis forces more gas and fluid into the loop, the twist or torsion acting as a check valve against its release. Occasionally, however some of the retained fluid and/or air can be forced from the loop permitting the occasional diarrheal stool reported. Dependent upon the degrees of rotation is the rapidity with which strangulation occurs; with strangulation the venous circulation is slowed and sooner or later mesenteric venous thrombosis, necrosis of the bowel and gangrene and perforation come about. If the ileocecal valve is competent in the patient with sigmoid volvulus a second closed loop obstruction may ensue between this valve and the point of volvular obstruction distally.

For both obstruction and impairment of circulation to a segment of colon torsion of at least 180° must occur. Torsion of less than this amount may and does occur without symptoms and can be considered physiologic. Beyond this degree of rotation axial rotation or twisting also occurs.[4, 12] Since this axial rotation is twice that of the mesenteric twist, their combination is complimentary and together they account for the obstruction of bowel lumen, the closed loop.

The clinical picture of volvulus is influenced most importantly by the degree and rapidity of twisting of the gut mesentery and the vascular occlusion which presages necrosis.[5] For this reason at least two clinical categories are described: the acute, fulminating picture of volvulus and the subacute progressive—often called chronic—type.

* Department of Surgery, University of Maryland, Baltimore, Maryland.

Hinshaw and Carter[2] in their review of sigmoid volvulus have separated these two categories as is shown in table 1.

This table serves to describe the clinical picture, in general, of these patients; it also indicates the possible clinical course and the urgency with which treatment must be undertaken. It must be pointed out that the acute fulminant variety of volvulus of the sigmoid colon is usually seen in younger individuals.

Among the more common etiologies often designated as important in the development of volvulus is chronic constipation. This factor is easily appreciated in patients with aganglionic megacolon; volvulus is less frequently entertained as an initial diagnosis in the older patient or the chronically ill individual who rather suddenly develops abdominal distention, abdominal pain and increasing constipation. Among the patients reviewed in this present study 43 per cent were patients confined to hospitals for the mentally incompetent[3] and half of them were beyond 50 years of age.[4]

It is recognized uncommonly that volvular obstructions of the colon are not infrequently associated with other intrinsic and coexisting colon lesions and with other physiologic and pathologic states. Ritvo, Farrell and Shauffer[6] have reported 12 cases of volvulus of the cecum half of which were precipitated by obstructing lesions in the more distal colon. Three of these were carcinomas of the descending and sigmoid colon and rectum. Watson, Varco and Schmid[14] have reported a patient with acute porphyria who presented with a volvulus of the cecum. In 1944 Kohn, Briele and Douglass[8] were able to collect from the world literature 41 patients with

FIG. 1. Appearance of torsion of colon characteristically seen with sigmoid volvulus.

TABLE 1

Chief clinical types (sigmoid volvulus)

	Acute Fulminating	Subacute Progressive
Previous attack	Infrequent	Frequent
Onset	Sudden	Gradual
Clinical course	Rapid, often catastrophic	Slow, but progressive
Pain	Diffuse, severe often steady	Less severe, occasional cramps
Vomiting	Early	Late, may be negligible
General appearance	Prostration, shock common	Shock uncommon or late
Distention	Less marked, may be none	Usually extreme
Signs of peritoneal irritation	Definite tenderness rebound or rigidity	Usually not present
Peristalsis	Violent hyperactivity; later silent	Usual pattern of colon obstruction
Leucocytosis	Frequent	Infrequent
Roentgen findings	Frequently not distinctive	Frequently diagnostic
Presence of strangulation	Frequent and early	Infrequent and late
Differential diagnosis	Perforated viscus or strangulated bowel	Obstruction of left colon

volvulus of the sigmoid and 19 patients with volvulus elsewhere in the colon, each associated with pregnancy. These authors reported an additional patient who had four episodes of volvulus of the pelvic colon associated in three instances with pregnancy before operative correction was accomplished. Hull[9] described the 11th such patient in the American literature and was able to report that in 1952 there were 96 such instances in the world literature.

This present survey covers the years 1937 to 1957 and consists of observation upon 37 patients admitted to the University of Maryland Hospital in this period. Twenty-nine of these had volvulus of the sigmoid colon and eight of the right colon and cecum. When the group is considered as a whole, the patients are equally divided between the two sexes. However, among the patients with sigmoid volvulus the males predominate in a ratio of approximately 60:40. Among the patients with cecal volvulus only one patient was a male.

The level of volvulus within the colon will dictate in some degree the therapy most properly required; volvulus of the cecum will require operation when this diagnosis is made. Access to this lesion by nonoperative efforts is not available as it is in sigmoid volvulus and prompt surgical attack is imperative.

The presenting signs and symptoms of cecal volvulus are not unexpectedly different from those produced by twisting of the sigmoid colon aside from the location of pain which may be right sided or in the epigastrium. Pain is usually colicky in character and vomiting is frequent. When the dilated, distended cecum lies high in the left upper quadrant it is often confused with a dilated, tympanitic stomach. When the correct diagnosis is in doubt, immediate barium enema will readily confirm the location of the obstruction. The absence of a palpable cecum in the right lower quadrant is of real clinical significance.

The series presented here consists of eight patients with volvulus of the right colon and cecum. Three were patients from hospitals for the mentally disturbed. All required operative derotation and three failed to survive. One of these, a 78-year-old woman, had the unusual combination of both cecal and sigmoid volvulus. Proctoscopic, nonoperative release of the sigmoid volvulus was readily accomplished but the abdominal signs failed to resolve; barium enema was required for a correct diagnosis. This patient survived operative reduction of the cecal volvulus, but died suddenly and unexpectedly 3 days after an elective sigmoid colon resection. Necropsy failed to show the exact cause of death. A second patient, a mentally disturbed woman, died of generalized peritonitis after dislodging her cecostomy tube, an operative technique used both to facilitate decompression and to aid in cecal fixation. The third death occurred in a patient with congestive heart failure and lymphatic leukemia. This patient was 73 years old and her death was attributed to a cardiac lesion. Operations upon the patients in this small group consisted of derotation and cecostomy in five instances, right colectomy in one patient and operative derotation with neither drainage nor resection in two patients. None of the five survivors are known to have had a recurrence of their episode of colon torsion. In none of the three patients who died could the cause of death be attributed to failure or delay in diagnosis or to the specific operative measures undertaken. It would appear then that under similar conditions no requisite modification of surgical treatment is implied in this review.

It may be of interest that cecal volvulus occurred in one patient with a full-term pregnancy. Rotation occurred about an adhesive band. This was severed at operation and the cecum derotated. Fixation of the cecum was not attempted because of marked displacement of the bowel at this stage of the pregnancy. The patient delivered a full term viable infant the first postoperative day and made an uneventful convalescence. This patient has been followed through three subsequent pregnancies and deliveries without further difficulty.

Most of the patients who develop volvulus during pregnancy do so in the third trimester. A smaller and nearly equal number are reported to do so in the second trimester and in the postpartum period. This observation appears most unusual for it would appear difficult indeed for gut rotation to occur at a time when the abdomen is so distended. In the patient reported above the etiology seems less obscure. The presence of an adhesive band about which the cecum could rotate is a sufficiently responsible etiology, in the presence of a rapidly enlarging uterus.

Twenty-nine patients had volvulus of the sigmoid colon; thirteen of these (45 per cent)

were inmates of mental hospitals. Treatment was as follows:

1. Nine patients were treated by Mikulicz type of resection, (one patient died postoperatively).

2. Eight patients had proctoscopic decompression (on one to three occasions) followed by elective sigmoidectomy. None of these patients died; however, the one patient listed among the cecal volvulus group had two lesions and succumbed following sigmoid resection.)

3. Six patients had operative derotation only. (One patient died following operation; no lesions are known to have recurred).

4. Three patients had operative derotation followed by later sigmoidectomy. (None of these patients died).

5. One patient had primary resection and anastomosis without complication.[10]

6. One patient died following proctoscopic decompression.

7. One patient was admitted in profound collapse and expired before operation could be performed.

Thus there are four deaths in this group of patients following a multiplicity of treatment methods:

(a) One patient did not survive sufficiently long for definitive treatment to be accomplished. Necropsy revealed gangrene, perforation of the bowel and peritonitis.

(b) A second patient died 44 hours after proctoscopic decompression, of bowel necrosis, perforation and peritonitis.

(c) The third patient had had symptoms for 6 days. At operation the sigmoid was derotated and a cecostomy was performed. A subsequent peritonitis dictated reoperation and a projected exteriorization of the sigmoid colon. At this second operation a generalized peritonitis was present because of leakage at the site of cecostomy. The patient did not survive the operation.

(d) A fourth patient did not survive a lower nephron nephrosis following a Mikulicz exteriorization.

This group of patients with sigmoid volvulus is small, the methods of treatment are varied and conclusions as to the most effective treatment measures cannot be drawn unequivocally. Nevertheless, it is well to take note of the one patient who had nonsurgical decompression of the volvulus 5 days after the onset of symptoms and who subsequently died of perforation and peritonitis. This instance again supports the observation that nonsurgical treatment of volvular obstructions is hazardous and may be acceptable only in very carefully defined instances. Of additional importance is the observation that 7 patients had nonoperative decompression of the sigmoid volvulus upon 11 prior occasions before more definitive surgical correction was accomplished.[1, 3] This may recur within a few hours after the initial reduction. It is likely that others may have had recurring subacutely obstructing symptoms upon occasion which in retrospect were caused by some degree of incomplete obstruction. The case histories of most of these patients are replete with statements of constipation and difficult evacuation of the colon. Such episodes serve to emphasize the likelihood to further volvular obstruction upon subsequent occasions and indicate that simple decompression of sigmoid volvulus thru the sigmoidoscope is not a definitive measure of therapy when used alone and without planned surgical intervention in the immediate future.

FIG. 2. X-ray taken with decompression tube in place.

Finally, 2 of these 29 patients were admitted with acute fulminating volvular obstruction. One individual was seen 4 hr. after the onset of his symptoms and the other 15 hr post onset. In

each instance, prompt operation was undertaken successfully.

Two of the patients with sigmoid volvulus were pregnant at the onset of their intestinal symptoms. One patient[9] was operated upon 24 hr. after induction of labor and a segment of necrotic colon was exteriorized and resected. A second patient is most interesting; her case history was reported upon a previous occasion.[8] Upon three occasions volvulus occurred during a pregnancy. The first occurred at 24 weeks gestation, the second at 28 weeks and the third at 32 weeks. Operative derotation was done on each occasion. Two months following the last operation, a fourth episode of volvulus occurred and a Mikulicz exteriorization and resection was accomplished. Upon each preceding occasion the patient failed to return for elective colon resection but did return each time when the acute episode recurred.

One patient is known to have had a rectal stricture beyond the point of volvulus and this was thought to have participated as an etiologic factor in the production of an episode of acute fulminating obstruction. None of the patients reported here had neoplasms at the time of development of this episode of volvulus. One with sigmoid volvulus had a small intraluminal polyp within the resected colon but it is inconceivable that this contributed in any way to the obstructive episode.

SUMMARY

Experiences in the treatment in the years 1937 to 1957 of 37 patients with volvulus of the colon are reported.

Eight patients had volvulus of the cecum and adcending colon and three of these failed to survive—a mortality rate of 37.5 per cent.

Twenty-nine patients had volvulus of the sigmoid colon and four of these died, a mortality rate of 13.8 per cent. One of these deaths occurred in a patient who was moribund upon admission and who failed to survive sufficiently long for operation to be performed.

Three patients in the entire series presented themselves with volvulus complicating pregnancy in the last trimester. In each instance both patient and baby survived.

No instances of either neoplasm or diverticulitis appear among this group of patients as an inciting factor in the production of volvulus of the colon although this is reported in other series. In one patient a rectal stricture may have been a leading cause of volvulus.

Sixteen patients (43 per cent) were inmates of hospitals for the mentally incompetent.

All patients with cecal volvulus were treated by immediate operation. A variety of operative techniques and nonoperative measures were utilized in the treatment of sigmoid volvulus. Nonoperative treatment was associated with a high incidence of recurrence of volvulus, and with death from necrosis of bowel and perforation in one patient.

University Hospital
Baltimore 1, Md.

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THE USE OF THE ILEAL BLADDER IN GENITOURINARY AND GYNECOLOGICAL SURGERY*

JAMES R. JUDE, M.D.† AND ROBERT R. SMITH, M.D.

Bethesda, Maryland

Urinary tract reconstruction is a frequent necessity for congenital, traumatic or operative defects. For the simpler lesions plastic reconstruction can be undertaken utilizing urinary tract tissue. The more extensive procedures require different techniques. Segments of terminal ileum have been found useful in many of these cases.

Urinary diversion is a recourse often needed permanently or temporarily. Nephrostomy and cutaneous ureterostomy have been used. Difficulty in caring for them, pyelonephritis, and stricture formation frequently result. The ureterosigmoidostomy of Coffey[8] is a valuable method also but is complicated by recurrent pyelonephritis and hyperchloremic acidosis.[12, 17] Variations in this technique[15, 21, 24, 27] have not eliminated these factors.

Reconstruction of damaged or destroyed ureters has been attempted with pedicled fallopian tubes,[33] blood vessel grafts,[18, 31] autogenous fascial transplants,[22] plastic devices[18] and bladder flaps.[2, 35] Only the use of bladder flaps for replacement of short terminal ureteral segments has proved successful.

Contracture of the bladder of any etiology or subtotal resection with decreased capacity often leads to serious renal consequences and severe subjective urinary tract complaints. Urinary diversion to the skin or large bowel or an indwelling catheter have been the usual treatment. The adverse effects have been described above.

An organ so anatomically located and physiologically constructed as to be of value for permanent or temporary urinary diversion, total or partial ureteral replacement, and enlargement of a contracted bladder is the terminal ileum. Tizzoni and Foggi[36] in 1888 employed a segment of ileum for enlargement of the bladder, called ileocystoplasty, in dogs. Finger[16] in 1894 proposed that a segment of small intestine without isolation from its mesentery be used to replace a destroyed ureter. This operation was performed experimentally by Caspare d'Urso and Achilles de Fabii[13] on dogs in 1900 and by A. E. Melnikoff[25] in 1912.

An 18-year old female with probable tuberculous contracture of the bladder and frequent micturition had the first recorded clinical application of diversion of the urinary stream to an ileal bladder. The operation, performed by Shoemaker[34] in 1906, was an anastomoses of the remaining good left ureter to an ileal segment. The diversion was only temporary because after one and one-half years severe skin irritation about the urinary ileostomy induced Shoemaker to attach the ileal conduit to the contracted bladder. The patient was reported to void well without symptoms and to be alive one and one-half years later. Shoemaker was therefore the first to use a segment of terminal ileum clinically for an external conduit (ileal bladder), for ureteral replacement, and for enlargement of a contracted bladder.

Like many great discoveries however, the clinical value was lost for several decades. Nissen[26] reported the successful clinical use of a segment of small intestine to replace a structural portion of one ureter in 1940. Scheele,[32] in 1941, anastomosed the center of an isolated loop of ileum to the bladder and joined the ends together creating a ring of ileum as a form of bladder enlargement. Urinary diversion in humans by use of an ileal bladder was revived by Bricker[4] in 1950. It is his method of ileal loop diversion that is now finding such wide application.

The relative ease and safety of creation of the ileal bladder, the low to absent incidence of damaging pyelonephritis or hyperchloremic acidosis and the simplicity of patient care of the urinary ileostomy have all added to its great value in gynecological and genitourinary surgery.

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† Present address: Department of Surgery, Johns Hopkins Hospital, Baltimore 5, Maryland.

From the Surgery Branch, National Cancer Institute, National Institutes of Health, Public Health Service, U. S. Department of Health, Education, and Welfare.

Radical pelvic surgery with removal of the bladder and distal ureteral segments necessitates urinary diversion.[7] Palliative diversion may also be necessary for unresectable lesions involving the terminal ureters and pelvis. The use of the ileal bladder in such instances removes the complications of nephrostomy, cutaneous ureterostomy or ureterocolonic anastomosis from adding to the problems of the debilitated patient.

MATERIAL

Twenty-two patients have been submitted to creation of an ileal bladder for urinary diversion at the National Cancer Institute in the past 18 months. The majority of these have been for far advanced cancer of the cervix uteri, many intractable to radiation therapy (table 1). Six were for palliative diversion of the urine from unresectable bladder tumors to allow intensive radiation to be undertaken. One was performed as a temporary diversion to allow adequate closure of a large vesicovaginal fistula occurring secondary to original treatment of carcinoma of the cervix.

The patient is physically prepared for operation by a mechanical cleansing of the bowel with cathartics and enemas. Sulfasuxidine is given daily for 6 days preoperatively and neomycin for 36 hr. before the procedure. The diet is gradually reduced from a low residue to a liquid died over the prior week. Supplementary parenteral Vitamin K is added to replace loss of the intestinal tract source.

The psychological preparation of the patient for surgery is as important as the technique of the operation itself. Inadequate knowledge by the patient of what is to be expected, especially when a total or anterior pelvic exenteration is also to be performed, make for difficult postoperative care. Well-informed patients readily accept the procedure when presented with the facts.

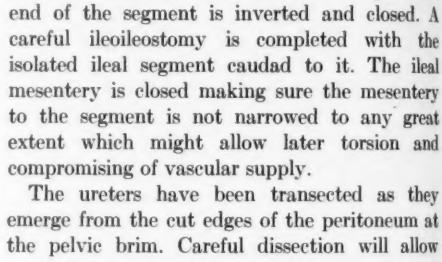
TABLE 1

Diagnosis of 22 patients with urinary diversion to an ileal bladder

Diagnosis	Number of Patients	
Carcinoma of the cervix		14
Stage III	2	
Stage IV	4	
Previous x-ray treatment	8	
Carcinoma of the bladder		7
Vesicovaginal fistula		1
Total		22

The method of construction of the ileal bladder is similar to that described by Bricker,[6] (figs. 1 and 2). In the majority of the cases reported here, a total or anterior pelvic exenteration was first performed. To encompass this area a long midline incision is made from the pubic symphysis to above the umbilicus. Following the multiviscera removal a segment of terminal ileum 15 to 25 cm. from the ileocecal valve is selected. The length of the segment to be isolated is dependent upon the anatomy and size of the patient with 20 to 25 cm. usually adequate. Careful preservation of vascular arcades insures its total viability. After division the proximal end of the segment is inverted and closed. A careful ileoileostomy is completed with the isolated ileal segment caudad to it. The ileal mesentery is closed making sure the mesentery to the segment is not narrowed to any great extent which might allow later torsion and compromising of vascular supply.

The ureters have been transected as they emerge from the cut edges of the peritoneum at the pelvic brim. Careful dissection will allow



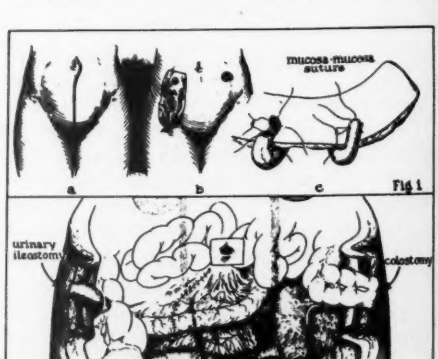


FIG. 1. (*a*) Incision; (*b*) final external appearance; (*c*) detail of mucosal-to-mucosal two-layer ureteral-ileostomy.

FIG. 2. Operation for formation of ileal bladder. Note the position of the ileal segment posterior to the cecum and over the sacral promontory. The drawing shows the ileal bladder in association with a total pelvic exenteration.

only sufficient ureter length to reach the ileal segment to be extraperitoneal. This will insure against impairment of ureteral arterial supply. The left ureter is anastomosed to a small 0.5-cm. stab wound in the posterior wall of the ileal segment about 2 cm. from its proximal end by a mucosal-to-mucosal suture. This consists of a suture of 4-0 chromic catgut, placed in each quadrant as the inner row. An outer layer of 5-0 inverting Lembert silk sutures grasps only the adventitia of the ureter and serosa of the ileum. The importance of turning in only a small cuff is emphasized to prevent uretero-ileal obstruction. The right ureter is similarly anastomosed 3 or 4 cm. further distally on the ileal segment.

Placement of the ileal loop can be somewhat of a problem especially with a low-lying cecum. In general, retroperitoneal placement behind the cecum prevents the danger of pockets in which loops of bowel can be incarcerated. The proximal end of the ileal bladder is anchored to the cut edge of the peritoneum along the left posterior pelvic wall. This attachment, along with its central portion held tightly to the sacral promontory by the ureteral anastomosis, permits the bladder to occupy a posterior position. Here it does not create a hazard to other viscera nor is it endangered by undue pressure exerted upon it or its vascular pedicle.

No attempt is made to reperitonealize and no peritoneum is placed over the ureteral-ileal anastomoses which are posterior to the ileal segment. Also, no catheters are placed into the ureters. A single early case in which this was done resulted in stricture formation at the anastomotic site and severe pyelonephritis.

The distal end of the ileal loop is brought through the abdominal wall at McBurney's point. A disc of skin and fascia, the diameter of the intestine, is excised to prevent obstruction at this point. Excess ileum is excised and the mucosa sutured to the skin margins by interrupted silk sutures. A good protuberant bud results. At the operating table, a disposable plastic bag is adhered to the skin about the ileostomy for immediate urine collection. Skin irritation from the urine is prevented, nursing care is made easy and a clear ready view of the ileal bud is always present.

With ileal bladder construction alone the abdomen is not drained. With pelvic exenterative procedures the pelvis is drained through the perineum. The abdominal wall is closed in a single layer with interrupted figure-of-eight 2-0 braided steel sutures. The midline incision enables both rapid entry and exit.

Blood is replaced as needed during the operative procedure as indicated by the patient's status and measurement of loss by volume and weight. In cases with associated pelvic exenteration measurement of loss is extremely valuable and with appropriate replacement insures a good postoperative course. One or two pints have been usually sufficient with ileal bladder construction alone. Were it not for the debilitated condition and low blood volume of the patients in whom the procedure is undertaken there probably would be no necessity of blood replacement since the operative loss is minimal. Pelvic exenterative procedures may entail as high as eight or nine blood units.

A gastric tube is inserted at the time of surgery. This is removed when indicated by decrease in return by Wangensteen suction. Alimentation is begun after bowel sounds have become active and flatus passed. The usual period of parenteral feeding is five to six days.

The various operative procedures for which an ileal bladder was constructed are listed in table 2. All pelvic exenterative procedures were performed for carcinoma of the cervix except for one anterior exenteration for a resectable bladder malignancy. To facilitate intensive radiation therapy or to alleviate associated urinary symptoms palliative diversions were performed in six patients. The temporary diversion of the urine away from the bladder to facilitate repair of a large vesico-ureterovaginal fistula was

TABLE 2

Operative procedures with construction of ileal bladder

Operative Procedure	Number of Patients
Total pelvic exenterations	11
Anterior pelvic exenterations	4
Permanent palliative diversion for radiation therapy of carcinoma of the bladder	6
Temporary diversion for transvesical repair of intractable vesicovaginal fistula	1
Total	22

performed in a patient whose case history is detailed below.

There was one operative death in this series. Complications attributable to the ileal bladder are listed in table 3. Although hyperchloremic acidosis was present in 4 patients the ileal segment cannot be implicated in 2 cases in which severe chronic pyelonephritis was present preoperatively. The other 2 patients have had chlorides as high as 118 mEq. per L. and CO_2 as low as 20 mEq. per L. They have always been asymptomatic and otherwise have satisfactory renal pictures.

The acute pyelonephritis occurred in the early postoperative period in each instance. One was associated with withdrawal of indwelling ureteral catheters, another with the performance of a retrograde radiographic study of the ileal bladder with regurgitation up the ureters. The third occurred with obstruction of a Foley catheter inserted into the ileostomy of the patient who had sensitivity to the ileostomy bag tape. The latter patient also had persistent late unilateral ureteral obstruction which was later corrected by re-exploration. The second case of persistent ureteral obstruction, the patient with slough of one uretero-ileal anastomosis and resultant urinary fistula and the patient with the ileocutaneous fistula were all reoperated upon early. The defects were successfully corrected.

A minimal to moderate hydronephrosis was common in the early postoperative period. Table 4 compares the pre- and postoperative pyelograms in renal units for those cases with early films and those with films in the later followup period. Note the improvement in the pyelograms occurring in the late followup. Figure 3, *a*, *b*, and *c*, are typical pyelograms showing the improvement that occurs. Renal units also frequently regain lost function as shown in figure 4, *a* and *b*. It is important that the ureters of nonfunctioning kidneys be anastomosed to the diverting urinary bladder since this return in function occurs in about two thirds of the cases. Persistent hydronephrosis is rare. As noted above it has occurred in 2 cases which were corrected by reoperation and a new uretero-ileal anastomosis.

Retrograde ileal bladder roentgenograms[22] were made in 11 cases by the introduction of Hypaque into the ileostomy via a Foley catheter. They proved of value in determining the rapidity of emptying of the ileal loop and helped define its function. The ureters did not fill routinely. In 2 patients they did not fill at all. In 4 patients a single ureter filled, and in 5 both ureters had regurgitated Hypaque up in the renal pelvis. This procedure is a method whereby the physiology of the ileal bladder may be studied and it may be helpful in delineating retention of urine or the cause of obstruction. In all our cases there was prompt emptying of all upper and lower urinary systems except for a single renal unit which admitted and held a small amount of radiopaque dye. The patient with this finding

TABLE 3

*Postoperative complications in 22 cases of ileal bladder construction**

Postoperative Complication	Number of Patients
Hyperchloremic acidosis	4
Acute pyelonephritis	3
Persistent ureteral obstruction	2†
Ileocutaneous fistula	1†
Allergy to ileostomy tape	1
Urinary fistula (ureteral anastomosis)	1†
Slough of ileostomy bud	1
Total number of *patients* with complications	8

* One case of persistent ureteral obstruction was a late complication. All others were early complications.

† Reoperation necessary.

TABLE 4

Pyelograms in the postoperative period

Renal Units	Pyelograms				
	N	Mi	Mo	Ma	0
Units followed: 0–1 month:					
Preoperative	19	3	3	3	7
Postoperative	11	10	7	4	3
Units followed: 3–16 months:					
Preoperative	15	2	4	2	6
Postoperative	18	5	4	0	2

N = normal intravenous pyelogram; Mi = minimal hydronephrosis; Mo = moderate hydronephrosis; Ma = marked hydronephrosis; 0 = nonfunctioning renal unit.

FIG. 3. (*Left*) Normal intravenous pyelogram four weeks before total pelvic exenteration. (*Center*) Pyelogram seven weeks postoperatively showing bilateral moderate hydronephrosis. (*Right*) Fourteen weeks postoperatively showing bilateral minimal hydronephrosis.

was subsequently reoperated upon and corrected for persistent hydronephrosis. The procedure should be attempted with care and only under aseptic conditions. It is not without danger as evidenced by a case of Gram negative septicemia associated with one ileographic study in our series.

The great majority of the patients had normal blood chemistries and electrolytes preoperatively (table 5). By one month postoperatively, the chemistries had largely returned to normal. In the late postoperative period a single patient had an abnormal BUN which was associated with obstruction of the ureteral ileal anastomosis by recurrent carcinoma of the cervix (table 6).

Sterility of the postoperative urine was seldom obtained. The preoperative urine however, also was usually not free of pathogens. Eight of ten urines cultured preoperatively were positive for pathogens. Twelve of thirteen cultured postoperatively were positive. The predominant organisms in both instances were *Pseudomonas aerogenosa* and *Proteus mirabilis*.

When the blood electrolytes and chemistries, the urine output, the intravenous pyelograms and the general state of the patient were considered, kidney function was felt to be satisfactory in 21 of the 22 patients at the last followup. The one unsatisfactory patient had uremia terminally from obstruction by recurrent cancer.

The followup on these patients is not long enough to draw any conclusions as to the results of the treatment of their cancer. There have been five deaths, one operative as noted above. Three died from recurrent cervical carcinoma after 5 months, 6 months and 8½ months. A 75-year-old male died of a cerebro-vascular accident,

TABLE 5

*Blood chemistries and electrolytes**

	Normal	Abnormal	Indeterminate
Preoperative	19	3	0
Postoperative			
0–2 weeks	13	9	0
2 weeks–1 month	17	3	2
4 months–18 months	17	1	4

* Number of patients with abnormal, normal or indeterminate blood chemistries and electrolytes in the preoperative and postoperative periods.

TABLE 6

*Classification of abnormal blood chemistries and electrolytes**

	BUN	CO_2	Cl	K
Preoperative	2	1	—	—
Postoperative				
0–2 weeks	8	2	3	—
2 weeks–1 month	2	—	2	2
4 months–18 months	1	—	—	—

* Distribution of abnormal blood chemistries and electrolytes in those patients in which they were abnormal in the preoperative and postoperative periods.

two months after palliative diversion for bladder carcinoma.

CASE REPORTS

Case 1.—The use of the ileal bladder for urinary diversion with total pelvic exenteration. A 61-year-old colored female was admitted with a diagnosis of untreated Stage IV carcinoma of the cervix. The bladder base was invaded and a vesicovaginal fistual was present. Intravenous pyelogram (fig. 5*a*) revealed nonfunctioning right and normal left kidneys. Blood urea nitrogen and electrolytes were normal. The patient was subjected to a total pelvic exenteration and construction of a 25-cm. ileal bladder. Four pints of blood were required as replacement during the procedure. The tumor invaded the parametrial nodes. Early postoperative pyelogram (fig. 5*b*) revealed a normal left kidney and late function of a hydronephrotic right kidney. Blood urea nitrogen and electrolytes were normal at all times. She was discharged taking adequate care of herself 25 days postoperative. Follow-up 13 months after surgery revealed a normal blood urea nitrogen and blood

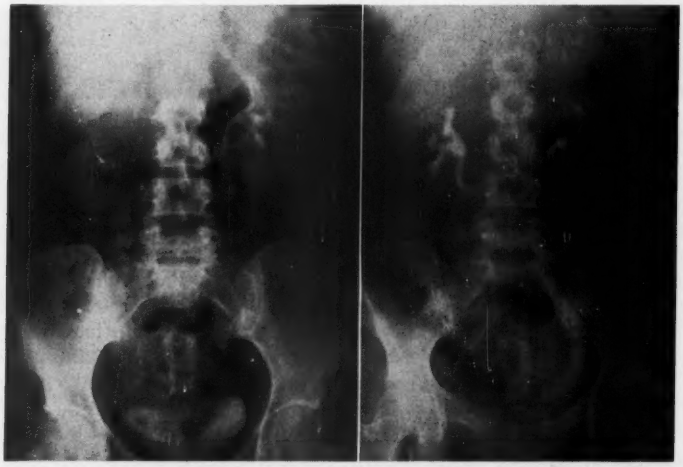


FIG. 4. (*a*) Pyelogram one week before total pelvic exenteration. The left kidney is normal and the right is nonfunctioning. (*b*) Twenty-two weeks postoperative films showing return of function of the right kidney by intravenous pyelography.

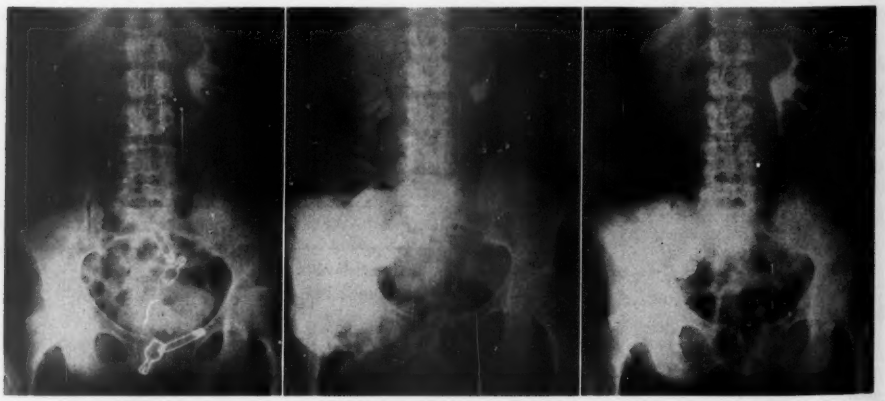


FIG. 5. (*Left*) Pyelogram one week before total pelvic exenteration showing a normal left kidney and nonfunctioning right kidney. (*Center*) A three-hour pyelogram film taken six months postoperatively showing a normal left kidney and some late function of a hydronephrotic right kidney. (*Right*) Thirteen months postoperative pyelogram with poor function of right kidney and normal left kidney.

electrolytes. Intravenous pyelogram showed good function bilaterally with moderate hydronephrosis of the right kidney and normal left (fig. 5*c*). She has no difficulties in caring for herself and has not altered her life because of the operative procedure.

Case 2.—The use of the ileal bladder as palliative diversion in carcinoma of the bladder. A 70-year-old white female with a nonresectable transitional cell carcinoma of the bladder had a normal intravenous pyelogram four months before surgery (fig. 6*a*). While receiving deep roentgen therapy she developed marked right and moderate left hydronephrosis (fig. 6*b*). There was no evidence of distal metastasis. Blood urea nitrogen and blood electrolytes were normal. *Escherichia coli* and *Klebsiella pneumoniae* were cultured from the urine. A palliative 25-cm. ileal bladder diversion was performed uneventfully with the patient receiving one unit of blood. No evidence of metastases was found. Early postoperative intravenous pyelogram (fig. 6*c*) showed a slight improvement in the hydronephrosis of the right kidney. Blood urea nitrogen and blood electrolytes were normal. The patient was discharged taking good care of herself 46 days postoperative. Follow-up intravenous pyelogram seven months later was normal (fig. 6*d*) as were the blood urea nitrogen and blood electrolytes. Cystoscopy revealed no evidence of tumor. She was continuing her life without any alteration caused by the ileal bladder.

Case 3.—The use of the ileal bladder for temporary urinary diversion to enable correction of intractable vesico-ureterovaginal fistula. A 47-year-old white female was admitted for a large persistent vesico-ureterovaginal fistula following radical hyster-

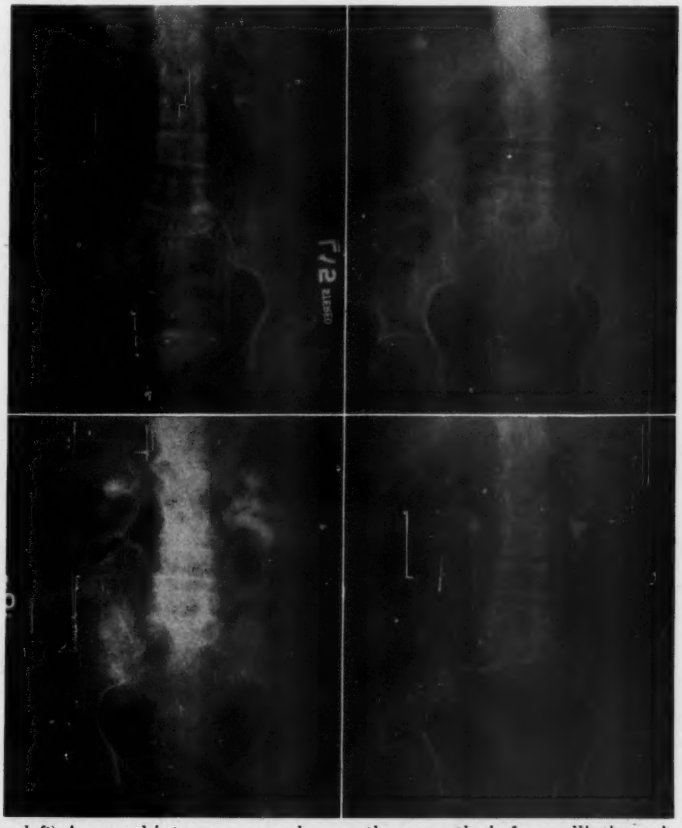


FIG. 6. (*Top left*) A normal intravenous pyelogram three months before palliative urinary diversion for carcinoma of the bladder. (*Top right*) Two weeks before surgery shows marked right and moderate left hydronephrosis. (*Bottom left*) One week postoperatively showing bilateral moderate hydronephrosis. (*Bottom right*) Seven months after urinary diversion reveals bilaterally normal pyelograms.

ectomy three and one-half months before for carcinoma of the cervix. She had had bilateral nephrostomies three months previously for urinary obstruction and recurrent pyelonephritis. On admission the left nephrostomy tube was nonfunctioning and urine was being lost via a large defect in the bladder base. The right nephrostomy tube functioned well. Intravenous pyelograms and a right nephrogram (fig. 7*a* and *b*) revealed relatively normal upper urinary systems but total obstruction of the distal right ureter. *Pseudomonas aerogenosa*, *Staphylococcus aureus* and *Klebsiella pneumoniae* were cultured from the nephrostomy tube. Blood urea nitrogen and electrolytes were normal. The patient was treated with Furadantin and submitted to construction of an ileal bladder and transvesical three-layer repair of the vesico-ureterovaginal fistula (fig. 8). No evidence of persistent or recurrent cervical cancer was found. Postoperative pyelograms (fig. 7*c*) were normal. The patient was discharged and returned two months postoperative for the second stage reconstruction of her urinary tract. Cystoscopic and dye studies revealed that the bladder was now intact. A laparotomy was performed, the distal end of the ileal bladder taken down, and an ileoneocystostomy performed (fig. 9). Again there was no evidence of cervical carcinoma. The patient had a benign postoperative course except for some difficulty with plugging

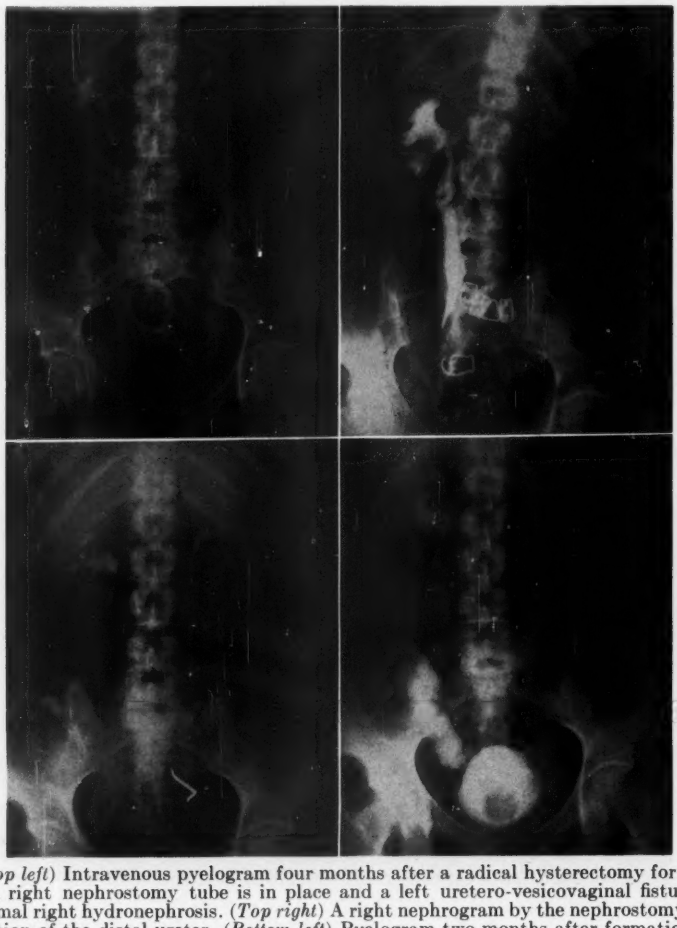


FIG. 7. (*Top left*) Intravenous pyelogram four months after a radical hysterectomy for carcinoma of the cervix. A right nephrostomy tube is in place and a left uretero-vesicovaginal fistula is present. There is minimal right hydronephrosis. (*Top right*) A right nephrogram by the nephrostomy tube reveals total obstruction of the distal ureter. (*Bottom left*) Pyelogram two months after formation of the ileal bladder is normal. (*Bottom right*) Ileocystogram one month postileocystostomy shows well the bladder, ileal loop and upper urinary system.

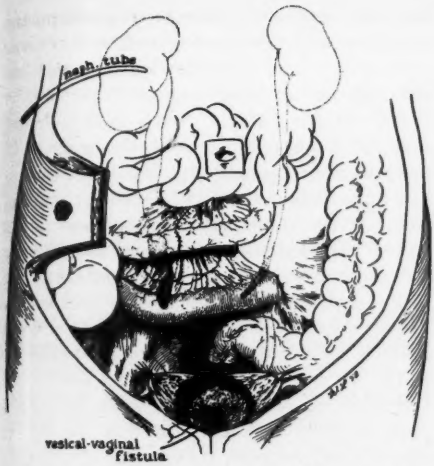


FIG. 8. Correction of intractable ureterovesicovaginal fistula: Formation of an ileal bladder and transvesical three-layer closure of fistula.

FIG. 9. Correction of intractable uretero-vesicovaginal fistula: Anastomosis of ileal bladder to autogenous intact bladder two months after the first-stage procedure.

of the indwelling bladder Foley catheter with mucus. On her last follow-up four months following the first stage and two months following the second stage, her blood urea nitrogen and electrolytes were normal. Except for minimal right hydronephrosis the intravenous pyelogram showed good function. A cystoileogram revealed reflux of the dye up both ureters with rapid emptying (fig. 7*d*). The patient voids without difficulty taking no longer than normal. Mucus shreds have been no problem. She is very satisfied with the procedure and has returned to teaching.

DISCUSSION

Ureters imbedded in the colon without diversion of the fecal stream are subject to invasion by Gram negative organisms with ascending pyelitis resulting frequently in permanent kidney damage. When the fecal stream is diverted this objection to use of the colon for urinary diversion is removed. However it has been shown that the colonic mucosae absorbs chloride ions in excess of sodium ions, with resultant hyperchloremic acidosis.[29] These two main objections to the use of colonic segments for bladder replacement are not found with the use of short segments of ileum. Utilizing the radioisotopes Na^{24} and Cl^{38}, Pyrah *et al.*[28] in 1955, demonstrated that Na and Cl were absorbed and excreted in the intact normal bladder in equivalent amounts. When the bladder was enlarged by anastomosis of a segment of ileum there was a slightly greater absorption of these ions than passage in the opposite direction. No hyperchloremic acidosis resulted since they were absorbed in almost equivalent amounts. Pyrah and Care[30] found that absorption of potassium into the blood stream would occur with the potassium concentration of average urine. With normal renal function and adequate urine output hyperkalemia was not felt to be likely.

The danger of emptying the urine excretion into lengthy segments of intestine has long been realized.[3] Eiseman and Bricker[14] showed that chloride and urea in normal urine concentration were indeed absorbed from an ileal segment in the human. However, they found no abnormalities in the blood urea nitrogen and chemistries of such patients. They suggested that the concentration of the electrolyte in the urine, the length of time the urine remains in contact with the absorbing surface of the intestinal tract, and the area of intestinal mucosa exposed to the urine were three factors which contributed to electrolyte reabsorption following ureteroenterostomy.

Urine concentration of electrolytes can be decreased somewhat by larger urine output. The duration of time the urine is in the intestinal segment is unimportant if the volume is not increased. Since new urine is always being added at one end as it is being removed at the other the time factor probably is cancelled. However, the surface area exposed to the urine is felt to be very important. When the ileal segment is only a

conduit it is small and contracted and the surface exposed is small. With storage of urine caused by obstruction or purposefully there occurs distension and presentation of a large surface area with concomitant relative increase in absorption. An increase in length of the segment even without distension would have the same final effect. Short ileal loops without obstruction enabling constant total emptying is felt to be of greatest importance in the prevention of large amounts of chloride absorption.

Only occasional persistent difficulty with electrolyte abnormalities in the absence of decreased renal function has been observed in this series. It would appear that the hyperchloremic acidosis seen was probably caused by absorption of chloride plus diminished renal function. Wilson[40] reported a single case of hyperchloremic acidosis which, similar to ours, had poorly functioning kidneys preoperatively and which also improved in the late postoperative period. The balance of these two factors as conceived by Lapides[20] in uretero-sigmoid anastomoses may determine the presence (of hyperchloremia) with the use of the ileal bladder. Most reports such as Bricker's[5] and Wawro[37] have emphasized the absence of this complication. Wells,[39] however, had an elevated serum chloride in 23 per cent of 96 cases.

Along with the shortest possible ileal loop also of greatest importance is the ureterointestinal anastomosis. Technically the most difficult part of the procedure—its proper completion insures healthy upper urinary systems. A viable terminal ureter and a bacteria-free intestinal segment allow scar-free healing. Incidental valve-like action is present in some of these anastomoses but is unnecessary. The peristaltic action of the ileum prevents regurgitation in the absence of obstruction.

Pyelonephritis has not been a problem in the absence of some complicating factor which reverses urine flow or mechanically transports organisms into the upper urinary system. This is a great improvement over the frequently seen recurrent and severe episodes with ureterosigmoidostomy. The low incidence of this complication has been recorded by Bricker[5] who found that in 65 patients, 8 had intermittent pyelonephritis and 4 others had pyelonephritis with hydronephrosis. Wells[39] found pyelitis in 11 of 156 patients. Cordonnier[9, 10] reported an incidence in 3 of 41 patients who had no mechanical obstruction to urine outflow.

Mortality from ileal bladder formation has been reported to be as high as 30 per cent by Wells[39] in 92 patients (when used following cystectomy for carcinoma). Annis[1] reported 25 per cent in 41 patients with bladder carcinoma, and Bricker[5] 14 per cent in 106 cases (81 cases of pelvic eviscerations, 16 cystectomies and 9 palliative diversions). In this series of 22 cases there has been one operative mortality. The high incidence of postoperative wound dehiscence, intestinal obstruction and ileus noted by Wells in 65 of 209 patients and by Cordonnier[9] in 7 of 41 patients also has not been seen.

Seldom has the use of an organ for such a physiologically different function proved so versatile and valuable. If the worry of morbidity of an intestinal anastomosis can be overcome it will find even wider application. The ureter is no longer as formidable and long losses may be replaced. Normal kidneys can be saved or prevented from the damage of permanent nephrostomy or cutaneous ureterostomy. Diversion either temporary or permanent can be accomplished. This safe reversible diversion may allow extensive plastic reconstruction of the bladder in congenital lesions such as exstrophy. If not, it may still allow a life with normal kidneys with permanent diversion of the urine. The contracted, painful bladder may be enlarged by ileocystoplasty. Action of intestinal smooth muscle with parasympathetic drugs reveals it responds remarkedly like the bladder. Urine expulsion with ileal enlargement of the bladder approaches normal.[38] As noted earlier Shoemaker[34] in 1906 already had applied the isolated ileal segment to such clinical use: urinary diversion (temporary), ureteral replacement, and bladder enlargement.

The psychological effect of passing urine from the abdominal wall can be very great if the patient is not adequately prepared for the possibility. If it is understood they quickly adjust to the life-saving procedure. Patient care of the ileostomy has been no problem with the use of disposable plastic bags. One patient did require a switch to a Rutzen bag because of skin irritation.

Follow-up support cannot be over-emphasized. This must be given not only from the aspect of care of the ileostomy but from the point of the

primary reason for the diversion. Although complications are rare they can be picked up early and adequately treated.

Patients have not regretted the operative procedure. They are able to socialize and work as before. Bag collection of urine and every-other-day function of the colostomy when associated have left no frequent toilet problems.

The use of the ileal segment has wide possibilities. Its future use should be extensive.

SUMMARY

The development and present use of an isolated ileal segment in gynecological and genitourinary surgery has been presented. Its value as a means of temporary or permanent urinary diversion, replacement of one or both ureters, or enlargement of a contracted or partially resected bladder have been discussed.

The results of urinary diversion to an isolated ileal loop associated with radical pelvic cancer surgery in 22 patients followed up to 18 months are detailed; there was one operative mortality. Pyelonephritis and hyperchloremic acidosis were infrequent and usually with antecedent cause. The use of the ileal bladder has proved simple, effective, and satisfactory for this type of surgery.

507 N. Wolfe Street,
Baltimore 5, Maryland

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PRACTICAL TECHNIQUES IN THE CARE OF THE BURN WOUND*

CURTIS P. ARTZ, M.D.

Jackson, Mississippi

Burn shock and toxins from the dead tissue of the third degree burn, have been attributed to be primary causes of death in severe burns. Advances in the knowledge of burn care during the past few years have permitted improved treatment of fluid and electrolyte imbalance, and therefore, fewer patients die from so-called "burn shock." The exact role of a toxin absorbed from the burned tissue has not been definitely assessed. It has been shown, however, that the toxicity that occurs in the severely burned patient immediately before death is usually accompanied by large numbers of bacteria in the blood stream.[1] Most of the patients who die following a very toxic period actually are suffering from a septicemia, the most frequent cause of death in severe burns. The chief problem, therefore, in the management of the large burn is the control of infection.

This emphasizes the importance of local care of the burn wound. The aim in the treatment of first and second degree burns is to provide an environment of cleanliness, so that the areas will heal free from infection. The aim in the local management of third degree burns is the early removal of dead tissue and closure of the wound as soon as possible with a skin graft.

IMMEDIATE TREATMENT OF THE BURN WOUND

Most second degree burns are very painful and must be covered immediately to protect them from the air. Greasy ointments are commonly used as first aid measures but they make adequate cleansing of the wound difficult. The simplest method of relieving pain is to protect the injured area from the air by covering it with a clean cloth.

All burns should be cleansed, followed by removal of blisters and detached epithelium. Masks should be worn by all those in attendance. In the extensively burned patient fluid and electrolyte replacement should take precedence over local care. A general anesthetic is contraindicated for cleansing the wound. Intravenous morphine will provide adequate analgesia.

The wound should be cleansed gently. Some type of bland soap and warm water should be used. The blisters and devitalized tissue can usually be pulled away by grasping the loose tissue with a dry pad. Sometimes it is necessary to use forceps and scissors. After the first cleansing procedure a second washing followed by rinsing with large quantities of water prepares the surface for definitive local care. The cleansing procedure should be carried out very rapidly to eliminate fear and discomfort for the patient.

DEFINITIVE LOCAL CARE

There are two commonly used methods of definitive local care, the exposure method and the occlusive dressing method. Soon after the reintroduction of the exposure method by Wallace[2] in 1948 it became a fad among surgeons. Its apparent ease of application made it very popular. In some institutions during the past several years it has fallen into disrepute because it has been used on improper indications. Its use in many clinics throughout the world has permitted a sound evaluation, and now the exposure method and the occlusive dressing method are used as complementary techniques according to well founded indications.[3]

The exposure method may be used if the burn is of such configuration that it can be easily and adequately exposed. Too frequently the exposure method is labeled as an open method of treatment, and its application is really neglect. The exposure method is actually a closed method because, when properly applied, the wound of a second degree burn becomes covered with a crust which closes the wound to invasion by microorganisms. In full thickness burns the dead tissue becomes dry and forms an eschar that serves as a protective covering for the wound. Unless these coverings of the exposed wound remain solidly intact, the technique becomes an open one, allowing for the ingress of bacteria.

* From the University of Mississippi Medical Center, Jackson, Mississippi.

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Areas treated by the exposure method must be completely exposed, and the covering that forms must be constantly protected against cracks.

One of the chief advantages of exposure seems to be its effective control of infection. Burns of the face are easily exposed. Because of the good vascularity of the face, rapid healing of partial thickness burns occurs and third degree eschars sequestrate early. Deep face burns should not be treated by exposure for a prolonged period of time. Third degree burns of the face do well when wet saline soaks are applied to the eschar about the eighth postburn day. This hastens the removal of the eschar and provides an earlier surface for grafting. Burns of one side of the trunk are particularly well suited for treatment by exposure. Circumferential burns cannot be adequately exposed and, therefore, require dressings. Since it is difficult to dress a burn about the perineum, exposure treatment is indicated.

The success of the exposure method depends almost entirely on how adequately complete exposure and immobilization of all burned areas can be achieved. The dry crust should be inspected under a good light each day to make sure that small areas with cracks or loosening beneath the protective cover are discovered. These should be trimmed and covered with moist fine-mesh gauze. Exposure ends in partial thickness burns when the crust desquamates and falls off. Exposure ends in full thickness burns when the eschar begins to soften and is ready for removal. Granulating surfaces should never be exposed, except in the late care of burns after grafting when only minute areas of granulating tissue remain between grafts.

Occlusive dressings should be used in all burns where the exposure method is not applicable. Like the exposure method, occlusive dressings must be properly applied and carefully managed. The aim of a good dressing is to cover the open wound to protect it from infection. It should not necessarily be a pressure dressing because pressure does not inhibit the loss of fluid. A dressing should be applied that will absorb the fluid, keeping the wound surface dry and thereby free from the growth of bacteria. It must also be occlusive to prevent the invasion of bacteria. The dressing should be applied with even resilient compression, in such a way as to eliminate dead space, to limit venous and lymph stasis, and to produce a splinting effect. The material placed next to the wound must not macerate the tissue or damage the remaining viable epithelium. Several types of fabrics are available. Dry fine-mesh gauze, lightly impregnated petrolatum gauze, or some of the commercially prepared nylon preparations are very satisfactory. Dry fine-mesh gauze and fine-mesh petrolatum gauze are harder to remove than gauze impregnated with a water soluble ointment.

Lightly impregnated petrolatum gauze can be made easily by placing roller gauze bandage in a jar, then adding 2 cc. of water and filling the bottom of the jar with white petrolatum.[3] On autoclaving, the hot liquid petrolatum permeates the tightly wound roller bandage. When the bandage is removed, the excess petrolatum may be scraped away from the outer layers, leaving a roll of lightly impregnated petrolatum gauze. The roll permits rapid application.

Outside the initial layer, there should be many layers of some type of absorptive material. To apply a dressing to an entire extremity or the trunk is quite time-consuming unless a one-piece dressing is available. A good one-piece dressing made of standard items has been designed at the Brooke Army Medical Center.[3, 4] A one-half inch layer of absorbent cotton, a section of soft fluffed gauze made by folding over several layers from the bolt, and an additional one-half inch pad of cotton are encased in a large single layer of bolt gauze. This dressing is thick, absorptive, and very pliable. A layer of fine-mesh gauze is placed over the wound before the one-piece dressing is applied. It can be fashioned in two sizes: one to fit the adult leg and the other to fit the adult arm. When children are being treated, smaller one-piece dressings may be made.

The initial dressing frequently can be left in place for 10 days. Thereafter dressings should be changed about every 5 days. The local application of an antibiotic at the time of the initial dressing is contraindicated. Antibiotics, applied locally, early in the course of burn treatment only make for the growth of resistant forms of microorganisms.

All circumferential burns should be dressed. Burns treated in out-patients should be dressed because the crust or eschar following exposure is easily broken, unless the patient is quiet in the hospital. All third degree burns of the hand should be dressed because the eschar separates

more rapidly beneath dressings and the area is ready for grafting earlier.

IMMEDIATE EXCISION AND GRAFTING

Immediate excision during the first two or three days postburn is a very desirable procedure since it permits removal of all dead tissue soon after injury. It has two distinct disadvantages: (a) Within the first few hours or even days it is difficult to determine accurately the extent of full thickness injury, and (b) surgical excision compounds the initial injury. In patients with burns not exceeding 15 per cent of the body surface, where there is definite evidence that the injury is of the full thickness variety, initial excision may be performed followed by grafting four days later. This method is particularly useful in full thickness burns of the dorsum of the hand.

The Surgical Research Unit at the Brooke Army Medical Center has attempted early excision of very extensive areas such as 30 to 40 per cent of the body surface.[5] Some of these procedures have been very successful, but the survival rate of patients after such massive excision has not been particularly higher than of similar patients treated by conventional methods. Massive excision is a complicated procedure and requires a large professional team. It is definitely not recommended for general use in the management of extensive full thickness burns. Further experience with massive excision by research groups may eventually prove rewarding.

REMOVAL OF THIRD DEGREE ESCHAR

One of the most important phases in the repair of full thickness burns is the aggressive approach to the burn wound. This means that the dead tissue must be removed as expeditiously as possible, and skin coverage must be achieved with the least possible delay. Grafts that are applied early after the burn seem to take well. As the postburn progresses the percentage of graft-take decreases considerably.

There are three acceptable methods for the removal of eschars; (a) repeated change of dry dressings; (b) wet soaks; and (c) surgical excision. Various types of chemical agents and enzymes have been used, but these do not seem to be any more beneficial than the use of wet saline soaks.

After about the 14th postburn day the full thickness eschar begins to slough and autolysis occurs beneath the dead tissue. Repeated changes of dry dressings every 2 to 4 days seem to aid in the removal of the eschar, keep the surface free of suppuration and prevent serious infection. As soon as a granulating bed is achieved, the graft may be applied.

Wet dressings keep the eschar soft and when they are changed, any loose portions of dead tissue can be removed. This technique is a very desirable method for hastening the removal of eschar and is of particular value in dirty wounds and wounds about the face. In some very large burns it is almost impossible to use wet soaks because of the configuration of the burned surface, the time involved and the pain that may be associated with application and reapplication of the wet dressings. When wet soaks are used the dressing should be changed down to the wound surface every 4 hours.

The most rapid method for removal of eschar is surgical excision. This would seem to be a very acceptable method of treatment, but an extensively burned patient cannot withstand the added stress of a major excision. In burns involving less than 15 per cent of the body surface, surgical removal of the eschar may be carried out safely. Excision may be undertaken as soon as the area of full thickness burn is clearly delineated. This may occur from the 8th to the 12th day. Early excision of full thickness burns of the hands is particularly desirable. Excision should not be used on the face. After the area is excised, a dry dressing can be applied and grafting performed 4 days later. If the area of full thickness burn cannot be clearly delineated, the use of wet dressings is preferred.

GRAFTING

Split thickness skin grafts should be applied to the third degree burned area as soon as the eschar is removed and the recipient site prepared. All granulation tissue is contaminated with many microorganisms. In spite of this fact, skin grafts will take unless the area is unusually purulent or Group A beta hemolytic streptococci are present.

Certain sites should have the priority for skin coverage. Areas around joints are covered before large flat surfaces, except in the very extensively burned patient, where rapid wound cover must be obtained to save the patient's life. In such instances, it is sometimes judicious to place postage stamp grafts over large areas of the wound

at the first grafting procedure to diminish the size of the open area. In most instances, however, skin should be placed first around the eyes and the hands, and then other areas of motion, such as about the knees, elbows and axilla. When only the leg is burned, priority should be given to the area around the knee and then the lower part of the leg, with the larger surfaces on the thigh being grafted later.

In extensive burns, flat surfaces may be covered with thin skin approximately 0.010 to 0.012 inches in thickness. Skin for areas over joints should be somewhat thicker, such as 0.015 inches.

The donor site to be used should be the most accessible area from which skin can be taken and the area properly exposed. Exposure of donor sites is a very desirable procedure and is discussed more completely in a subsequent section. In extensively burned patients, every available area of skin should be used as a donor site. This may include the dorsum of the foot, the arms and unburned areas between granulating surfaces. It may be necessary to take several crops of skin from the same area. The patient with large burn wounds can be given better care on a Stryker frame.[3] This permits frequent turning and provides an easy method for exposing donor sites on the posterior surface of the body. Grafting may need to be planned in accordance with the areas available for donor skin. It is frequently possible to graft anterior wounds from a donor site on the anterior aspect of the body at the first grafting procedure and then turn the patient on a Stryker frame 10 to 14 days later and remove skin from the posterior aspect of the body to cover posterior recipient sites.

Cutting the skin. A variety of instruments are available for obtaining a split-thickness skin graft. The use of the electric dermatome is one of the outstanding advances in the care of burns in the past several years. With this instrument it is easy to obtain large sheets or multiple small split thickness grafts. During extensive grafting procedures the period of anesthesia is shortened considerably by the use of the electric dermatome. When skin must be taken from irregular areas, infiltration of the subcutaneous tissue with saline provides an even, firm surface for cutting the graft. This is particularly true on the feet, the anterior aspect of the chest and the arm.

The Padgett type dermatome is very useful on certain areas of the body, particularly over a thin chest or on the abdomen. The wide sheets of skin available with the Padgett dermatome are particularly useful as skin cover around joints such as the dorsum of the hand, axilla and popliteal areas. In many grafting procedures both types of dermatomes may be used advantageously.

Application of skin to the wound. As soon as the skin has been removed, it should be put in a basin of sterile saline solution to keep it moist. The nurse can then "back" the strips of skin with petrolatum impregnated gauze to make handling easier.

Three methods of application of skin grafts may be used: (a) lay-on method; (b) postage-stamp method; and (c) suture method. If adequate skin is available, the best method for applying split thickness grafts to large flat surfaces is by the lay-on method. The sheets of skin are placed on the wound and the petrolatum gauze backing removed. The skin is then pushed into position so that there is very little space between the strips. The grafts are held in position by a firmly compressed bulky dressing. When there are very extensive areas to be covered and a minimum amount of skin available, grafts cut about 1 by 2 inches in size may be placed in bricklayer fashion, not further than one-half inch apart. In areas of motion, such as around the joints, especially on the hand and in the axilla, it is usually necessary to suture large sheets of skin in place. After they are applied, small perforations must be made in the grafts because serum may collect beneath the skin and prevent a good take.

One of the most important factors in grafting is the application of the dressing as it maintains the grafts in place. In some instances it is wise to use a stent dressing which is particularly useful on uneven surfaces. As soon as the grafts have been applied, strips of lightly impregnated petrolatum gauze may be placed smoothly over them to fix the grafts in place and prevent slipping. A large number of moist fluffed gauze sponges or Kerlix gauze may be used to cover the petrolatum gauze. On top of this layer a large bulky occlusive dressing such as the previously described one-piece Brooke dressing must be applied with even resilient compression. The dressing should be changed about every 5

days after the grafting procedure. Sometimes it is necessary to incorporate a splint in the dressing to provide adequate immobilization.

HOMOGRAFTS

For permanent wound closure, third degree burns must be grafted with autogenous skin. In very severely burned patients the use of temporary skin cover with homografts may be life-saving. The homografts persist for approximately thirty days and serve as a "biological skin dressing," preventing infection and the loss of body fluids.[6] In some instances autografts may be available to cover a portion and homografts may be used for the remainder. It is wise to apply homografts in seriously debilitated patients until nutritional status improves and autografts may be taken. Homografts may be obtained from live donors or recently deceased bodies. Postmortem homografts take well and an abundant quantity may be easily obtained.[6] The decision to use homografts is always determined by the size of the wound and the general condition of the patient. If it seems impossible to obtain autografts to close the wound in a reasonable period, then the use of homografts as a biologic skin cover is indicated.

TREATMENT OF DONOR SITE

For many years the accepted method of treatment of donor sites has been the application of a large bulky occlusive dressing. Infection frequently occurs on the moist surface beneath the dressing, and in more recent years it has been found advantageous to treat donor sites by the exposure method.[3] Immediately after the skin has been removed, the donor area is covered by fine-mesh gauze. A warm moist gauze pad is applied for hemostasis. At the end of the operation the gauze pad is removed leaving the fine-mesh gauze over the wound. Blood caught in the interstices of the gauze forms a firm coagulum which protects the wound. This coagulum dries, becomes hard within 24 hr. and serves as a good protective covering. There may be moderate pain in large donor sites treated by exposure, but this usually disappears at the end of 24 hr. Epithelization proceeds beneath the coagulum and the area will usually heal in 12 to 14 days.

In extensively burned patients, donor sites treated by dressings frequently become infected and convert to granulating surfaces. Exposure of the donor site aids in the prevention of infection and is a significant advantage in the management of burns.

LATE CARE OF THE BURN WOUND

After the first dressing change following the graft, other dressing changes should be carried out at 2- to 5-day intervals. If the wound has not been completely covered at the first grafting operation, application of additional grafts should be performed as rapidly as possible. One of the great failures in the treatment of burns is to wait for prolonged periods between grafting procedures. If small uncovered areas remain, postage stamp grafts should be applied.

As soon as the uncovered areas are less than 2 cm. in diameter, the wound may be exposed. The patient may be put in a Hubbard Tank or the injured part exercised in water twice daily. This cleans the wound surface and promotes ingrowth of epithelium. The small open areas of granulation tissue should be covered with strips of fine-mesh gauze between baths.

When a patient with burns of the lower legs becomes ambulatory he must wear a rubberized elastic bandage. Such a bandage supports the circulatory mechanism and the freshly grafted areas thereby preventing venous stasis, breakdown of epithelium and subsequent ulceration.

MAINTENANCE OF BLOOD VOLUME AND NUTRITION

A primary facet in the support of the extensively burned patient during the grafting period is the maintenance of blood volume. It may be necessary to give transfusions as often as every other day. The hematocrit must be determined twice a week, and sufficient blood given to maintain a hematocrit of 45 or above. Large quantities of blood are required for three reasons: (a) the life of the red blood cell in the burned patient is not as long as in a normal patient; (b) considerable blood is lost from the oozing granulating surfaces, particularly at the time of dressing change; (c) infection present on the granulating surfaces depresses the formation of erythrocytes by the bone marrow.

A high protein-high caloric intake is essential. The usual daily protein requirement is 2 to 3 gm. per kg. Approximately 50 to 70 calories

per kg. should be given daily. This large intake is frequently impossible using the usual hospital diet. Supplemental high protein liquids must be given between meals. It is essential that such supplemental liquids be palatable so that the patient will consume large quantities during the prolonged period of convalescence. In some instances it may be necessary to use tube feedings or a high caloric protein hydrolysate mixture intravenously.

Routine daily vitamin supplements for adults are recommended as follows: thiamin—50 mg.; riboflavin—50 mg.; nicotinamide—500 mg.; ascorbic acid—1000 to 1500 mg.

AN ILLUSTRATIVE CASE HISTORY

The following brief case history illustrates many of the important facets in the care of the extensively burned patient (fig. 1). C. W., a 19-year-old white man, experienced a burn of 60 per cent of the body surface, of which 44 per cent was third degree, in a diesel oil fire at an oil derrick on October 20, 1957. He received deep third degree burns of both lower extremities, the buttocks; second degree burns of the hands and face. There was damage of the anterior cortex of each tibia.

In an attempt to prepare the wound for grafting as early as possible, dressing changes were performed every 3 to 5 days. On the 22nd postburn day, all dead burned tissue was removed gently, under anesthesia with very little bleeding. The dead bone was chiseled away. After another dressing change the first grafting procedure occurred on the 29th postburn day at which time 320 square inches of skin were removed by the Padgett and electric dermatomes from the anterior

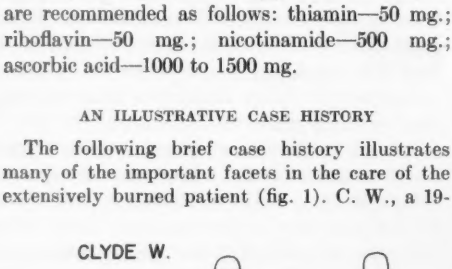

FIG. 1*A*. Pertinent data on illustrative case.

FIG. 1*B*. Third degree burned surface during autolytic or sloughing stage on 16th postburn day.

FIG. 1*C*. Wound completely covered and patient ambulatory at time of discharge on 108th postburn day. Note sheets of skin in critical areas such as popliteal spaces, lower legs and perineum. Larger flat surfaces were covered with postage-stamp grafts. For standing and walking both lower extremities were supported with rubberized cotton elastic bandages.

aspect of the chest and abdomen and applied to the penis, scrotum, knees and lower legs. The patient was on a Stryker frame. The second grafting procedure was carried out on the 40th postburn day when 180 square inches of skin were removed from the back and the posterior aspects of the arms and placed over the buttocks, perineum and posterior portions of the lower legs.

Additional skin cover was applied rapidly as follows:

45th postburn day—52 square inches of skin from anterior surfaces of both arms were applied to the anterior aspects of the thigh;

55th postburn day—120 square inches of skin taken as a second crop from the lower chest and upper abdomen and were placed on the thighs;

60th postburn day—40 square inches of skin taken as a second crop from the arms and as a second crop from the upper chest and put on buttocks and thighs.

In each instance the donor sites were selected so that the areas could be treated by the exposure method. At the end of 60 days postburn almost all of the wound was completely covered. The patient required a few other small operative procedures for additional application of skin followed by 3 weeks of physiotherapy. On the day of discharge, February 5, 1958, 3⅓ months after injury, all wounds were completely covered and he was walking.

Supportive therapy during his hospital course included the administration of 62 units of blood. He experienced 20 general anesthetics and 7 operative procedures other than dressing changes. During his course in the hospital, he received supplementary high protein liquid between-meal feedings and was given 80 liters of a protein hydrolysate, fructose, alcohol mixture.*

This patient had a very extensive burn but vigorous supportive therapy combined with an aggressive attack on the burn wound to achieve coverage as rapidly as possible produced a very satisfactory result.

* Amigen 800 supplying 37½ gm. of protein and 800 calories per L. furnished through the courtesy of Mead Johnson Company, Evansville, Indiana.

University of Mississippi Medical Center
Jackson, Mississippi

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Editorial

WHO SHOULD OPERATE?

No one could legitimately challenge the concept that, ideally, surgical operations should be performed only by those well qualified by aptitude and training. Furthermore, under ideal circumstances they should be performed in institutions well equipped for proper diagnostic study, providing adequate operating rooms, good anesthesia, competent ancillary aid from radiologists, pathologists, physicians, pediatricians, etc. Circumstances should be such that the patient is carefully watched day and night during his convalescence. He should be able to obtain such treatment without burdensome financial embarrassment. It is often preferable that he be treated close enough to his home so that his family can be near him. Proximity to home, however, is never as important as proficiency of professional care.

Fortunately, progress in medicine is continually making it possible for more and more patients to have a ready access to ideal surgical treatment. More and more competent specialists in all fields are being trained. There is a steady growth in the number of adequately equipped hospitals. Improved transportation facilities have brought most of our population within easy reach of such facilities.

Yet no one would deny that a great many operative procedures are being performed day after day by practitioners who are not trained for the therapy they undertake. There are some who feel that their license permits them to undertake any challenge with which they are confronted. Though this may be legally true, it is not morally or professionally right. In the hands of the most accomplished, a certain minimal risk exists for any given operative procedure. This is of necessity greater in the hands of those less well qualified and in institutions providing the bare necessities, rather than all potentially useful physical equipment and professional aid. We must be concerned also with the fact that our objective is not only to provide the patient with maximum safety but also with maximal benefit. The patient surviving an inadequate surgical procedure has not received the treatment he deserved. We must recognize that each of us varies in the scope of his proficiency. Not every one who can perform an appendectomy or herniorrhaphy adequately can carry out a good radical operation for cancer of the rectum. Not every one accomplished in abdominal surgery is adept in pulmonary resection or in cardiovascular surgery.

There are some who feel that every hospital of moderate size should aspire to all types of therapy. I can see no more justification for this than for each college to desire to expand into a university or each shop into a department store. Some types of treatment are too burdensome an undertaking, and unnecessary in view of the limited demand. Let me illustrate with the problem of open cardiac operations using extracorporeal circulation. Undoubtedly the apparatus itself will become more dependable, less complicated and less expensive as progress continues. It seems unlikely, however, in view of experiences to date, that the best interests of patients will be served unless those utilizing such equipment thoroughly familiarize themselves with it through animal experimentation before putting it into clinical usage. Most small hospitals provide no experimental laboratory. If they undertook such experimental studies they would find them unbelievably costly. However, once the apparatus was completely understood and a team organized for operating it efficiently, little proper service could be rendered unless the institution also provided competent diagnostic studies, such as cardiac catheterization and cineangiography, as well as vigilant postoperative care. It is doubtful that the demand is great enough to justify such elaborate physical equipment and professional help in small community hospitals.

It seems evident that those of us who utilize operative surgery as a method of therapy have very real responsibilities. We must prepare ourselves well and must continually make every effort to improve not only our technical proficiency but our understanding of the physiopathology of the various surgical illnesses and of pre- and postoperative care. We must do everything possible to help qualified and ambitious young medical graduates obtain the professional training they seek. I have the conviction that

the broader our background and the better our preparation, the more we realize our limitations as well as our capacities. It is more often the poorly trained who recognize no limitations.

Patients come to us full of trust. It is our obligation to help them to the best of our ability. This often entails advising them as to where and by whom they can best be treated. I know of no practitioner who has lost stature in the eyes of his patients or his professional colleagues by referring to others patients with problems he feels can be better managed by them. We are not expected to be proficient in everything.

HARRIS B. SHUMACKER, JR., M.D.
1100 West Michigan Street
Indianapolis 7, Indiana